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CONTINUOUS ANALYSES OF GASES, DUST AND FLAME DURING AND AFTER BLASTING IN CANADIAN SULPHIDE ORE DEPOSITS

(DSS Project No. 14SQ.23440-7-9140)

by

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KEY WORDS

Blasting
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Dust Generation
Flame Propagation
High-speed Filming
Secondary Sulphide Dust Explosion
Sulphide Dusts
Vibration Analysis

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SUMMARY

The objectives of this project were to: collect data regarding dust and flame emissions generated by development blasts; and measure SO_2 emissions produced by secondary ignitions. This will provide a better basis for developing improved technology regarding causes, prevention and control of sulphide explosions.

Dust and flame emissions were characterized by measuring these parameters along with blast vibration traces in both waste and sulphide rock over a period of two weeks. The results indicate that sulphide explosions in development headings may be prevented by reducing the powder factor used and installing short delay caps in the cut. It is recommended that this be verified by testing various blast patterns, and that the blast be filmed to document flame generation.

An SO_2 sensor was designed and built by NTC, to measure SO_2 emissions generated by development and production sulphide ignitions. The sensors were evaluated by the University of British Columbia, at Westmin mine, and performed extremely well. The SO_2 levels measured varied from 10-900 ppm. It is recommended that a modified version of this sensor be adapted for mine re-entry monitoring.

SOMMAIRE

Le présent projet avait pour objectif de mieux comprendre le processus entrainant un explosion de sulphure lors du sautage primaire de galerie de développement souterrain. Pour y arriver, la génération de poussière et de flamme à dû être caractérisé.

L'émission de poussière et flamme ont été charactérisé en mesurant ces paramètres à partir d'instruments de mesures quantitatifs et également de méthodes qualitatives, tel les films vidéo. Les résultats indiquent qu'il existe une possibilité d'éliminer les explosions de sulphures dans les galeries de développement en réduisant le facteur poudre et introduisant des iniateurs d'explosifs à périodes courtes. Il est recommandé de vérifier cette hypothèse par l'évaluation de différents patrons de sautage, tout en filmant le sautage afin de documenter la génération de flamme.

Un senseur de SO_2 a été conçu et assemblé par le CTN, afin de mesurer la concentration de SO_2 généré par les sautages de production et développement. Les senseurs ont été évalué par l'université de Colombie Britannique, à la mine Westmin, et ils ont bien performés. La concentration de SO_2 mesuré varit entre 10 et 900 PPM. Il est recommandé d'adapter une version modifiée de ce senseur pour la vérification en continue de la concentration de SO_2 souterre.

1. OBJECTIVES

The objectives of this project were to: collect data regarding dust and flame from emissions generated by development blasts; measure SO_2 gases produced by secondary ignitions. This will provide a better basis for developing improved technology regarding causes, prevention and control of sulphide explosions.

The project was divided into four phases:

Phase 1 - Instrument Selection and Testing

In this phase, the instruments required for acquiring essential data on dust, flame and SO_2 generation were identified, and a detailed plan on how each was evaluated and integrated was prepared.

Phase 2 - Instrument Acquisition and Check-Out

The instruments selected in Phase 1 were purchased, bench evaluated, fine-tuned, and assembled into the overall systems.

Phase 3 - In-Mine Evaluation

In-mine evaluation of the dust and flame monitoring instrument systems were conducted in development headings. The SO_2 sensor evaluation were conducted in both development and production blasts. To conduct the in-mine work, NTC successfully elicited the cooperation of both Brunswick and Westmin mines. It was decided to carry out the SO_2 evaluation at Westmin with the assistance of University of British Columbia and the dust and flame monitoring at Brunswick, with the assistance of ETA (formerly DuPont Explosives).

Phase 4 - Report

A report was prepared, providing all the details of the work and recommendation for further work to improve monitoring, prevention and control technologies.

The present report represents Phase 4 of the project. The SO_2 and the dust and flame work are presented in separate sections.

2. SO_2 MONITORING

2.1 Instrument Selection

Phase 1 involved identifying or designing an SO_2 sensor to evaluate the generation of SO_2 in sulphide mines. The first step was to select the concentration range required. Lab studies at CANMET had already shown that the SO_2 concentration in a 22 L explosion chamber could reach 1% (10,000 ppm) with pure pyrite([1]). However, in-mine tests with draeger tubes at Westmin had not indicated a concentration of more than 100 ppm when averaged over 20 minutes following the blast([2]). This suggested that we would require an instrument with capabilities for monitoring accurately (+/- 1%) at both low ranges (0-100 ppm) and high ranges (>1000 ppm).

A review of available instruments indicated that there were four sensors with the concentration range, cost and reliability required. A solid state instrument operating by infrared and made by Spanair of South Africa was first evaluated because of its wide concentration range, but was quickly abandoned because of the prohibitive cost of the filter element. An electrochemical sensor was not favoured because of the drifting problems experienced with these instruments in the past, however, a new electrochemical cell by City Technology was identified which did not have the drift problem (according to the British National Coal Board).

The City Technology electrochemical cells were supplied in two versions: a 0-2000 ppm cell and a 0-100 ppm cell. To have a very accurate concentration throughout the 0-2000 ppm range, the two different cells were mounted together in a stainless steel enclosure. The 0-100 ppm cell signal was electronically modified to react only in the 0-25 ppm range, thereby increasing the accuracy to +/- 0.5 ppm. The 0-2000 ppm cell was not modified. Both output signals were then amplified to a 0-1V output and connected to a data logger, also contained in the stainless steel enclosure. The cells were powered by a small rechargeable battery pack which could provide up to 16 hours of operation.

2.2 In-Mine Evaluation

Phase II involved evaluation of the instruments and documentation of SO_2 generation at Westmin. To complete this phase, a sub-contract was awarded to the Mining Department of the University of British Columbia. As part of this sub-contract, UBC was also asked to evaluate and define the present state-of-the-art for SO_2 detection monitors. The field test was done at H-W Mine of Westmin Resources Limited, Campbell River, B.C. The results of the field testing and the state-of-the-art SO_2 evaluation are presented in Appendix B.

In summary, the span, zero drift, and stability for all sensors were acceptable. The 3ST (0-100 ppm) was found to have 0.9% of full-scale drift for span and 0.5% of full-scale drift for zero readings, while the 3SF (0-2000 ppm) sensor showed 1.1% of full-scale drift for readings. Field testing of the sensors showed that they were dependable and accurate.

Over a period of two weeks in June 1988, UBC monitored four secondary sulphur blasts with two of the SO_2 units described above. Three occurred during silling operation in the K330 stope. The drill pattern when silling a production stope is similar to the drill pattern in a drift blast. The maximum concentration measured was when two adjacent panels were blasted simultaneously. Over 900 ppm was recorded and 200 m of ventilation tubing was damaged and burned. In addition, compressed air and water pipes were damaged, and two shift production delays were experienced. The SO_2 required two hours to clear out.

One blast was recorded in a production long hole blast. The maximum concentration reached was 10 ppm, and 45 minutes was required for gas clearance.

3. FIRST FIELD STUDY ON DEVELOPMENT BLASTING

3.1 Blast Design

3.1.1 Development Blasting Techniques

In development work, blasting round design can vary from slashing, driving raises or development drifts, or a complex series of shots involving long holes to develop undercut for block caving. This report will concentrate on development drifting only.

The ideal sequence of drifting consists of drilling, blasting, and mucking a complete round per shift. The drill pattern, depth, number of holes, drilling and mucking equipment, ventilation, etc... are therefore designed to achieve this circle.

Generally, the first hole or group of holes fired in a blasting round are known as the cut holes or cut portion of the blast. The principle upon which standard rounds are based is the drilling of cut holes, which will provide the proper relief for the remaining holes in a properly delayed round. The cut is the most critical part of the round because the balance of the holes yet to fire cannot possibly pull to the desired depth unless the cut comes out as planned. The most common type of round employed in development drifting in Canada is known as the "Canadian cut" or "burn cut". The actual design of the cut will vary greatly depending on the rock conditions and drilling equipment.

In a burn cut round, all boreholes are drilled parallel to each other. In the burn cut itself, one or more holes are left empty to provide relief for the fragmented rock that is to be ejected.

There are several types of burn cut patterns differing primarily in the location and amount of empty holes provided. Generally, the greater the volume of void space, the deeper the round can be drilled and successfully pulled. Soft, porous or highly fractured rock is more difficult to break than brittle rock and will require more void space and more loaded holes in the burn cut. The easer holes (non-loaded holes) can be drilled at the same size as the loaded holes (1 1/4 - 2 3/4" dia.) or at a larger size (3 - 5" dia.).

In preparing the delay sequence of the round, the burn cut must be fired first. Sufficient time must be allowed in between the blasting of the burn cut and the sequential rows of holes so that the rock has ample time to move out, thereby avoiding plugging of the opening and freezing of the round. Long period delay caps (LP caps) manufactured by CXA are commonly used for this application. They provide up to 8 seconds of delay between the first hole and the last hole fired (see Table 1).

Table 1 - CXA LP Caps

Delay Number	0	1	2	3	4	5	6	7	8	
Delay Time (MS)	0	490	800	1125	1400	1675	1950	2275	2650	
Delay Number	9	10	11	12	13	14	15	16	17	18
Delay Time (MS)	3050	3450	3900	4350	4850	5350	5900	6550	7250	8050

The explosives used for drifting can vary greatly. In most civil tunnelling work, water gel or other water resistant explosives are used, but in mining ANFO is by far the most popular explosive. Ammonium Nitrate/Fuel Oil (ANFO) is popular because it is a very inexpensive and a relatively safe explosive which can be set-off with a No. 8 detonator (does not require a booster in small diameter holes). For underground blasting, it usually comes in 25 lb bags and can be easily loaded into the holes with a pneumatic loader. The ANFO will usually be loaded all the way to the collar. If the holes are wet, ANFO may be replaced with packaged Water Gel or emulsion explosive. For this reason, lifters or bottom holes are usually always loaded with packaged explosives.

To avoid damaging the walls and back of the tunnels, the perimeter holes are sometimes loaded with isanol or decoupled packaged explosives. Isanol is composed of ANFO and polyethylene spheres which will reduce the detonation and borehole pressure of the ANFO, thus reducing wall damage. Packaged explosives are decoupled by using spacers between each stick or using very small diameter sticks.

3.1.2 Drifting at BMS-M

BMS-M has developed 15 types of burn-cut and six types of round pattern for their drifts (see Appendix E). The reason for such variation is that the geology plays a large role in the efficiency of a round blast, and to accommodate the changing geology between the orebody and the waste rock sediments, the round design had to be redesigned accordingly.

The round dimension will vary in size, but most will have 12'H x 18'W dimension to accommodate the largest diesel equipment. Typical advances are 12 feet per round. Hole diameter is 1 7/8" for loaded holes and 2 1/2" for non-loaded holes. Most drilling work at Brunswick is carried out with a three Boom Pneumatic Jumbo.

The holes are completely loaded with ANFO (to the collar) and fired with LP caps. Isanol was tested in perimeter holes, and although successful at controlling back break, it was discontinued.

3.1.3 First Field Trial Set-up

Two full rounds were drilled and blasted in a dead-end exploration drift on 575 mL No. 2 sub. The rock in this zone is composed of waste material. The waste material is formed of small quartz veins in a carbonate matrix. This rock is moderately fractured and very soft. As a consequence, more holes are required to properly blast the rock, and a 54 hole design with a full cut (13 holes, 6 are easer holes) was drilled during our tests (Figure 1).

The cut (seven loaded holes) was always blasted separately from the slash during the tests, and all holes were loaded fully to the collar with ANFO. By blasting the cut first, it was possible to evaluate its contribution to the total dust volume generated.

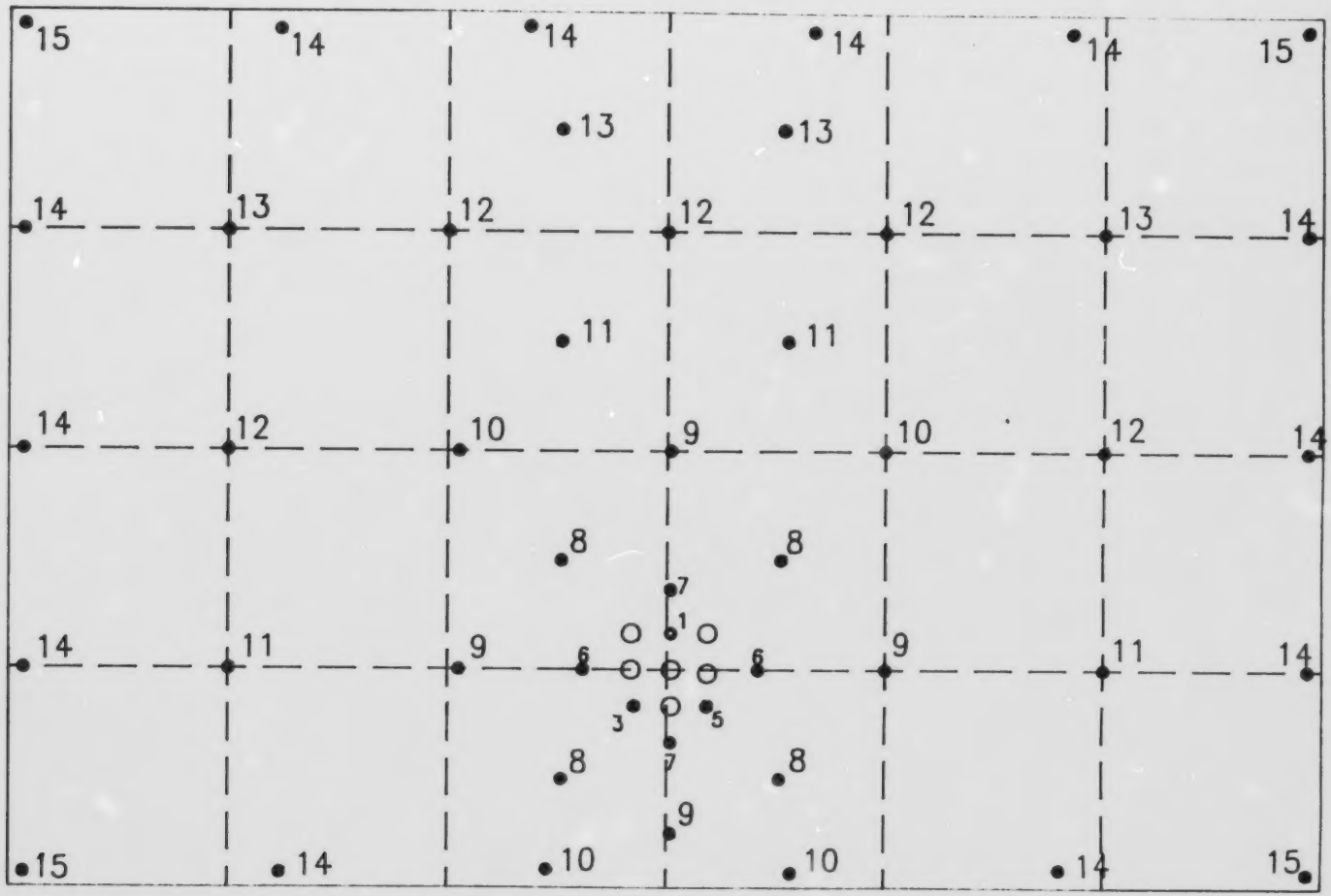


Figure 1 Field Trial Drift Design

3.2 Instrumentation

Dust Analysis

Three general methods can be employed to measure dust-cloud concentrations: i) sampling techniques in which a portion of the dust cloud is captured by aspiration, or impingement on a retrievable filter; ii) sampling techniques in which pans of a large area are used to collect settling dust at given distances from the blast; and iii) optical techniques utilizing the principle of light (visible or infrared) scattering.

Each method has advantages and drawbacks. The first two methods will only give a time-averaged result, but will be essential for acquiring data on size distribution and volume of dust generated. The third method will give a good indication of the variation of dust concentration over time.

The three methods were used in the survey. For dust sampling, a hi-vol pump with a flow rate of 35 CFM and a filter diameter of 4" was used. For collection of settling dust, eight 4'x 5' galvanized steel plates were used. Also, dust traps were made up to capture the dust at different intervals during the blast. The dust traps are simple galvanized steel chambers with a retractable spring-loaded door at each end of the chamber, held open by the piston of a solenoid valve.

To analyze dust decay, two instruments were used, a USBM design forward light scatter dust probe and a Mie Instrument RAS II 90° light-scattering dust sensor. The dust probe was designed to only respond to large particles (600 um and greater), while the RAS II was designed to respond preferentially to 0.1-15 μm particle size.

The technical data on the dust probe, RASII sensor, hi-vol sampler and dust traps are presented in Appendix F.

Gas Analysis

To determine the composition of the atmosphere in the vicinity of the rock face during the blast, the gases can either be analyzed continuously with an array of gas sensors or drawn up in a vacuumed vessel and subsequently analyzed by gas chromatography with flame ionization detection.

The second method was favoured due to its ease of installation and low cost. Four stainless steel cylinders of 0.5 L were fitted with 1/8" orifice solenoid valves. These cylinders were then vacuumed with a diaphragm pump just before being installed in the drift.

Data Recording and Triggering Method

To record the data from the dust probe and the RASII, a Toshiba portable lap top computer and a Mat-Lab I/O card were used. Both were mounted in a portable aluminum suitcase. The output of the dust probe (0-5V) and the output from the RAS II (0-IV) were connected to the input/output card. The software to record the event was written in "C" language by NTC. It was also designed to trigger the recording. Once the computer was turned on, software would start to monitor the input channels and calculate the change between two consequent records. When this difference passed 0.2 V, the recording of each channel was triggered. This would happen when the first hole was blasted and the dust from this hole passed through the dust probe nearest the face.

The Mat-Lab card was capable of scanning the channels at 1 MHz, providing a recording of 1 sample/MS.

To trigger the vacuum chambers and the dust chambers, an accelerometer and timer system was used. The accelerometer was installed 100 ft. from the face. Its sensitivity was adjusted to trigger on the firing of the surface electric cap. Once triggered, the geophone would, in turn, trigger the timer system which was adjusted to power-up the solenoids of the dust and gas chambers in a pre-programmable sequence.

The sequence chosen for all tests was a time interval of 5 seconds between each chamber. Since there was four chambers of each type, the sampling was completed after 20 seconds from the time the first cap was fired. Each solenoid was powered for two seconds. After the blast, the four gas cylinders were collected, and their contents were transferred into a single 2 L Tedlar bag with the use of a diaphragm pump. The four samples were combined to ensure a sufficient sample volume for lab analysis.

The dust collected in the dust chambers was brushed out and weighed. The set-up of all the instrumentation inside the tunnel is illustrated in Figure 2.

Film Instrumentation

Explosives Technologies International (ETI) was sub-contracted to assist us in the research by providing the film equipment as well as the personnel and expertise to operate the instrument.

The following instrumentation was provided by ETI:

1) 16 mm Redlake Locam II camera complete with film, lenses, power supply and related accessories capable of framing rates of 500 FPS.

2) 8 mm Sony video Camcorder complete with related accessories.

3) 35 mm SLR camera complete with Polychrome CS film, remote shutter release.

4) Sony SL-HF900 Super Beta Video Cassette Recorder complete with jog shuttle system.

5) 15 mm LW Model 224 A Photo Optical Data Analyzer

The Locam II and Sony Video were used to record the evolution of dust, degree of dispersion, velocity of movement and any flame front associated with the test round.

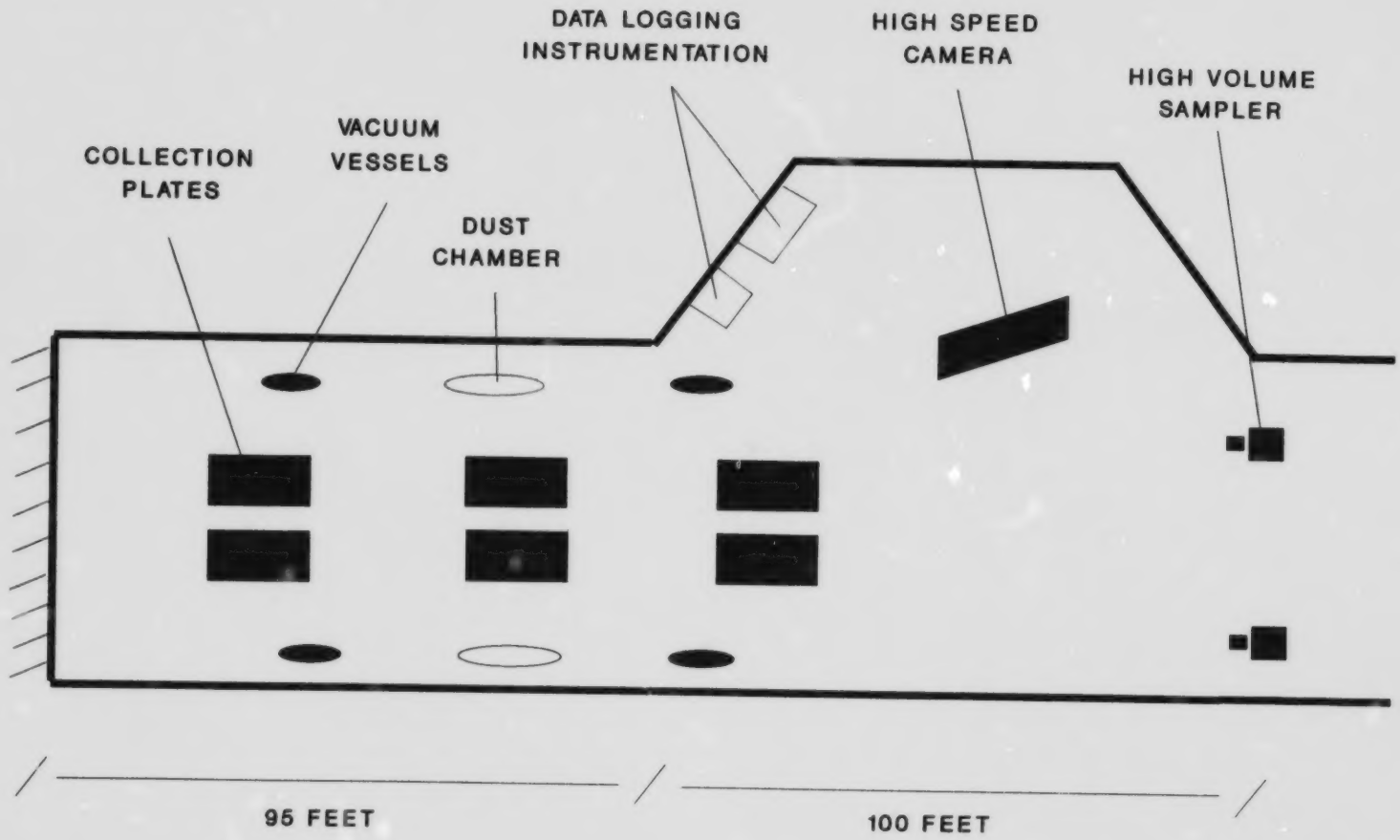


Figure 2 Illustration of Instrumentation Set-up in the Development Drift

The Locam was installed 100 ft. from the blast in an aluminum enclosure with a shock-proof Luxan window. The triggering of the camera was obtained by the breaking of an electric loop wrapped around the surface delay cap. The video camera was installed 250 ft. from the blast without protection. It was turned on manually by the project personnel just before exiting the tunnel. (Note that all personnel were on surface during blasting.)

The 35 mm camera was combined with a remote shutter release to use open shutter techniques to record the cumulative flame or high luminescent areas of the drift face. The film was processed immediately in the field to determine optimum exposure details. The camera was triggered using the same electric loop as the Locam camera. The video cassette was later reviewed and edited at ETI's offices with the Sony Beta Recorder, and the high-speed film was interpreted using the 16 mm data analyzer.

To record the evolution of dust and degree of dispersion during the blasts, it was necessary to light up the face with high intensity lamps. The lamps chosen were ELH slide projector lamps. They were mounted on a wooden frame, 25 ft. from the face, and the wood frame was bolted to the entire perimeter of the tunnel (excluding the floor). An attempt was made to protect the lamps with Luxan plates, but the high heat intensity propagated by the lamp would distort the Luxan. They were left unprotected during the trial.

3.3 Results

3.3.1 Dust and Gases Analysis

Composition of Gases

In the first test, we encountered a problem with the triggering system, and the vacuum bottles were not set off during the blast. The remaining tests were successful, and the following results were obtained from gas chromatography and CO_2 infrared analysis:

TABLE II - GAS MONITORING

	PPM			
	CO	NO	CO_2	NO_2
Cut No. 1	N/A	N/A	N/A	N/A
Slash No. 1	510	305	10100	260
Cut No. 2	60	12	2600	5
Slash No. 2	2005	422	N/A	210

The oxygen balance of the chemical formulation in a given explosive is the determining factor when evaluating post blast fumes. Most commercial explosives are mixtures of compounds containing four basic elements: carbon, hydrogen, nitrogen and oxygen. Other compounds and elements may be added as catalysts and sensitizers to produce some desired effects. The explosives manufacturer's goal is to design the amount of each of the components so that there is an oxygen balance to ensure complete oxidation of the products. If the correct amount of oxygen is present, all of the carbon is oxidized to CO_2 and the hydrogen to H_2O; the nitrogen is released as free nitrogen (N_2). An excess of oxygen in the explosive can result in the formation of nitrogen oxides (NO and NO_2) and a deficit of oxygen can cause carbon monoxide (CO) formation.

Koplin([3]) indicates that when an explosive detonates, the chemical decomposition consists of a rapid succession of exothermic reactions which produce large quantities of heat and very high gas pressures. The gaseous products which are produced in the detonation zone behind the wave front are not only products of complete decomposition (CO, H_2O, N_2) but also significant quantities of products of incomplete decomposition as well as radicals and elements (CO, OH, H_2, H, O_2, O, NO, NO_2). Other products as HO_2, HCO, H_2O_2, N_2O, HCN, NH_3 and CH_4 can also be formed, but in trace quantities.

Garcia and Malcomson([4]) monitored the gases from explosive detonated in an underground mine. The tests were done during drifting operations and the rounds were 6'W x 8'H x 6'D. Approximately 25 holes were fired per round and the holes were loaded with the following explosives: Dupont Tovex 100 and 220 (water gel with aluminum powder), Atlas Powermax 140 (emulsion) and Ireco Iremite 42 (emulsion). Ammonium nitrate/fuel oil explosives were not tested. The drift was sealed off for every round, creating a sampling chamber of 4000-9000 ft^3. CO, CO_2, NO and NO_2 were monitored in the chamber immediately following the blast. Table III summarizes the test results. These results cannot be directly compared to our results as in our tests, the area was not sealed off and the explosive quantity and composition was different. However, it can be noted that they are in the same range.

Table III - Gas Concentrations From Different Explosives (after Garcia, 1986)

		PPM			
Explosive Type	Volume of Chamber (ft^3)	CO	CO_2	NO	NO2
Tovex 100	5487	701	8033	432	240
Tovex 220	5623	977	6222	496	481
Powermax 140	4739	1932	8755	545	386
Iremite 42	9292	635	4568	111	38

The United States Bureau of Mines classifies explosives as permissible or non-permissible. Permissible explosives are approved by the USBM for underground coal mines and are limited in the amount that can be fired in a single round. Permissible grades cannot produce more than 5.6 ft^3 of noxious gases per lb of explosive. Small-scale experimental tests carried out by the USBM([4]) has shown that prilled ANFO can produce up to 2 ft^3/lb of noxious gases. If all the rounds were shot at once, there would be 700 ft^3 of gases released (approximately 350 lbs/ANFO/round at BMS-M) excluding the generation of N_2 produced by the reaction. This could have a significant effect on the oxygen concentration at the face. However, since the

holes are shot at intervals, the gases are diluted rapidly before and in-between each delay. In our results, the noxious gases concentration averaged over the duration of the blast did not go above 2% which indicates that oxygen concentration at the face during the blast is probably not significantly reduced, and therefore always sufficiently high to sustain a dust ignition.

Dust Analysis

a) **Dust Chambers**

The dust chambers were not very effective during the tests because they did not operate efficiently. Some results were obtained, however, and they are presented in the following table:

TABLE IV - DUST CHAMBER SAMPLES

Date	Explosion	Distance	Weight	Concentration
03 October	Slash	40 ft.	2.11 g	847 mg/m^3
03 October	Slash	50 ft.	3.82 g	1534 mg/m^3
03 October	Slash	60 ft.	1.28 g	514 mg/m^3
05 October	Cut	40 ft.	5.35 g	2148 mg/m^3
05 October	Cut	60 ft.	1.75 g	703 mg/m^3

As can be seen the concentrations are very inconsistent within the same blast. The concentration was calculated based on the full weight present in the chamber after the blast. The true concentration is less than this calculated value since the chamber is exposed to the atmosphere for a finite time following the blast and some dust is accumulated. The dust was not size classified in the laboratory because there was an insufficient quantity.

b) **Hi-Vol Samplers**

The results that were obtained with the Hi-Vol are found in Table V.

c) **Collection Plates**

The results that were obtained with the plates are found in Table VI.

The concentration presented in the table is, as with the dust chamber, not the true concentration since it is assumed that all the dust is deposited instantaneously. In reality, the dust is deposited over a period of 1 to 2 minutes with the first 30 seconds probably being the most critical.

The cut is blasted within three seconds, and over 90% of the -600 μm dust remains air-borne over this time (based on deposition of spheres in free air; Stokes law). The concentration calculated and presented in Table VI is probably close to the true concentration for the -600 μm dust. Over 600 μm, the dust tends to deposit much faster, so that the concentration calculated in meaningless.

For the slash, the duration of the blast is eight seconds, and within this time, 20-30% of the -600 um dust will be deposited. The concentration presented in Table VI is therefore higher than the true concentration.

The -600 μm dust was further classified into various size fractions (see Table VII and Figures 3,4,5 and 6. The table shows that a considerable part of the samples is less than 38 μm is size.

From the results of the plate collection, it was shown that the dust concentration created by a cut or slash is usually above 500 mg/m^3, and of the dust which remains air-borne for a period of over one second; a large portion is below 38 μm is size. In a 1 L explosion chamber, a concentration of 500 mg/m^3 is the minimum explosive concentration for pure pyrite. Also, 38 μm dust is several times more reactive than 60-70 um dust.

TABLE V

HI-VOL SAMPLES

Date	Type	Area	Distance (ft.)	Sampling Time (min.)	Weight (gm)	Concentration (mg/m3)[1.]
29 September	Cut	Floor	150	85	2.80	450
		Back	100	85	2.51	405
3 October	Slash	Floor	150	-	NA	NA
		Back	100	-	NA	NA
5 October	Cut	Floor	60	95[2.]	5.15	840
		Back	60	95[2.]	8.16	1.32
5 October	Slash	Floor	60	75[2.]	6.15	1.00
		Back	60	75[2.]	13.82	22.50

1. The filters were plugged up and the motor was not pumping upon re-entry.
2. It is assumed that 99% of the dust was accumulated on the filters within the first 5 minutes of the blast (the hi-vol flow = 35 cfm)

TABLE VI

COLLECTION PLATE SAMPLES

Date	Type	Distance (ft.)	Total Weight (gms)	Conc. (mg/m^3)	Weight (-600 um) (gms)	Conc. (mg/m^3)
29 September 1988	Cut	71	1326	195	1044	153
		63	2063	303	1128	166
		54	3417	503	1880	276
		44	3343	492	1412	207
		34	9306	1368	2580	379
		30	10907	1604	3390	498
3 October	Slash	78	783.7	115	490	72
		68	1770.3	260	1086	159
		60	3723.6	547	1496	220
		53	8325	1224	2667	392
		48	6507.3	957	2250	330
		43	9684.3	1424	2838	417
5 October	Cut	67	2422	356	819	120
		62	1097	161	590	87
		55	1035	152	721	106
		43	9874	1452	1539	226
		40	6297	926	1749	257
5 October	Slash	73	4245	624	1822	268
		63	2854	419	1492	219
		53	3069	451	1101	162
		43	4115	605	1478	217

TABLE VII

SIZE CLASSIFICATION OF SAMPLES

Sample[1]	(%)						
	-600 um/ +212 um	-212 um/ +149 um	-149 um/ +106 um	-106 um/ +75 um	-75 um/ +45 um	-45 um/ +38 um	-38 um
29-09-71	4.5	6.0	4.9	7.0	7.9	2.8	66.8
-63	9.8	7.5	5.7	7.1	7.3	3.3	59.2
-54	14.6	7.4	6.2	5.9	7.9	3.3	54.7
-44	14.7	8.2	4.9	7.0	8.0	2.8	54.5
-34	33.0	8.7	4.7	6.4	6.6	2.1	38.6
-30	28.2	12.8	6.2	6.1	6.3	1.6	38.8
03-10-78	2.9	6.9	8.9	11.9	13.7	3.7	51.9
-68	4.6	9.5	9.1	7.5	15.4	4.7	49.2
-60	12.0	12.0	9.5	11.1	10.0	3.8	43.9
-53	20.6	20.6	11.4	10.8	8.8	2.4	38.6
-48	21.8	21.8	13.2	7.6	8.9	2.2	38.8
-43	29.1	29.1	12.0	8.2	7.2	1.8	38.1
05-10-67	24.4	11.6	6.8	3.9	6.4	5.2	41.7
-62	14.8	10.9	7.1	7.0	7.9	2.8	49.4
-55	8.6	9.9	25.9	6.4	9.1	2.6	57.5
-43	30.2	13.7	5.7	5.2	5.6	2.1	37.5
-40	25.2	11.8	7.8	6.0	6.1	2.7	40.3
05-10-73	16.2	12.4	8.9	9.5	10.7	3.3	39.0
-63	14.8	12.0	10.0	8.6	12.1	3.2	39.3
-53	19.3	13.2	9.2	8.5	10.2	2.8	36.7
-43	16.1	10.6	9.0	10.6	9.2	5.3	39.1

1. Sample number coding is as follows: x-y-z; x is the date, y is the month, and z is the distance in feet from the face.

SIZE CLASSIFICATION

Samples 29–16

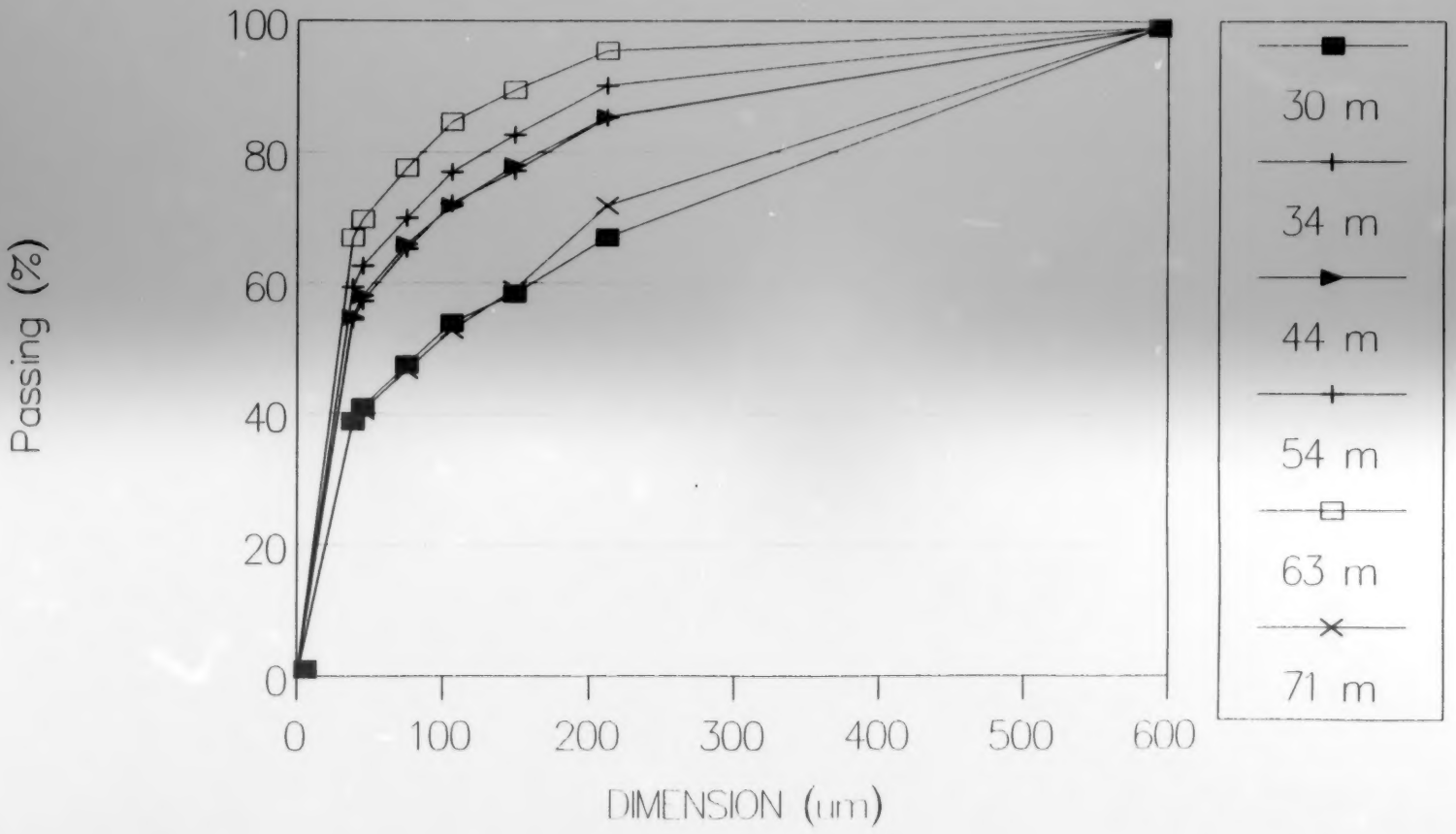


Figure 3 Graphical Representation of Collection Plate Samples (29 Sept.)

SIZE CLASSIFICATION

Samples 03–01

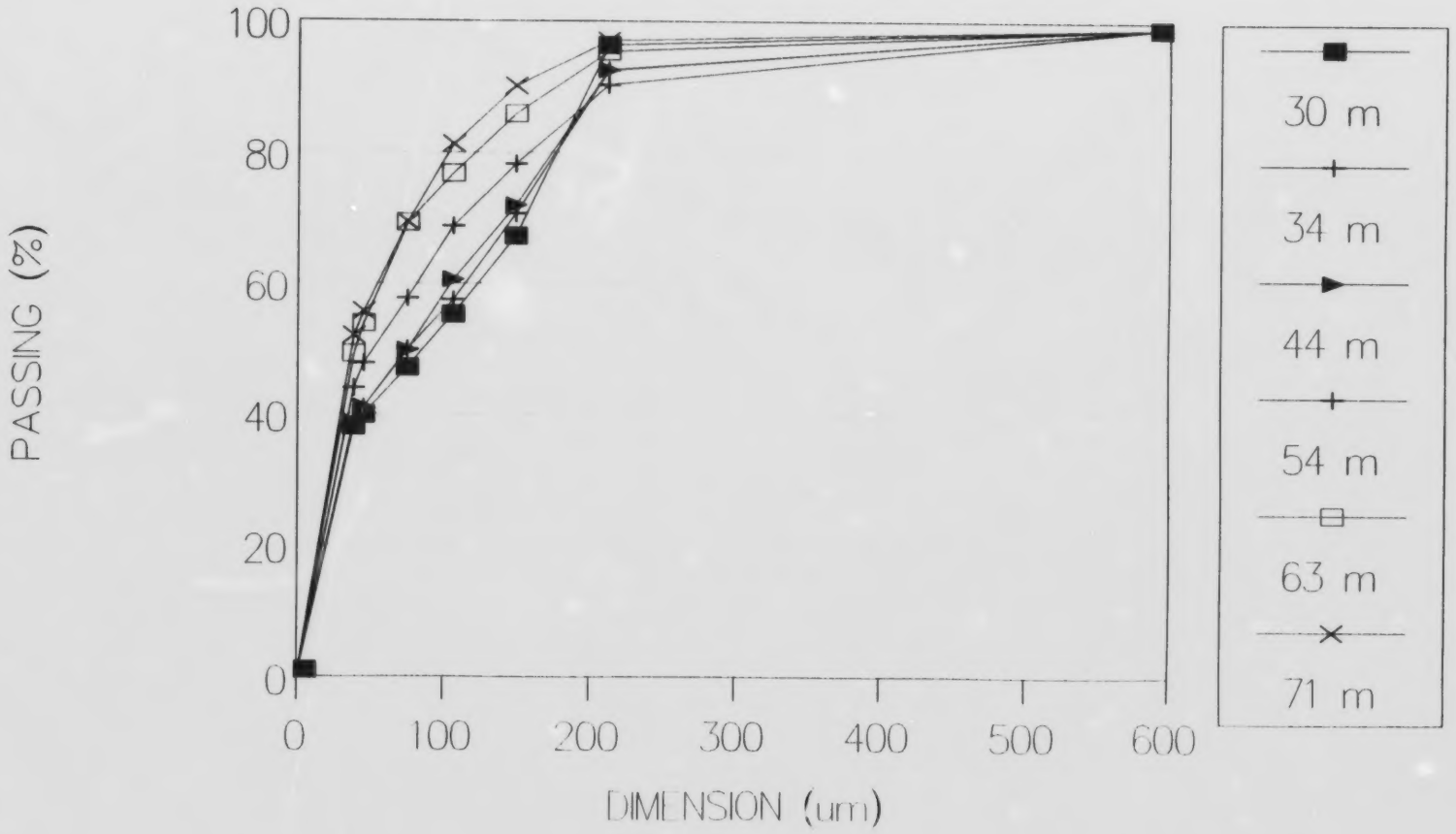


Figure 4 **Graphical Representation of Collection Plate Samples (3 Oct.)**

SIZE CLASSIFICATION

Samples 05–01

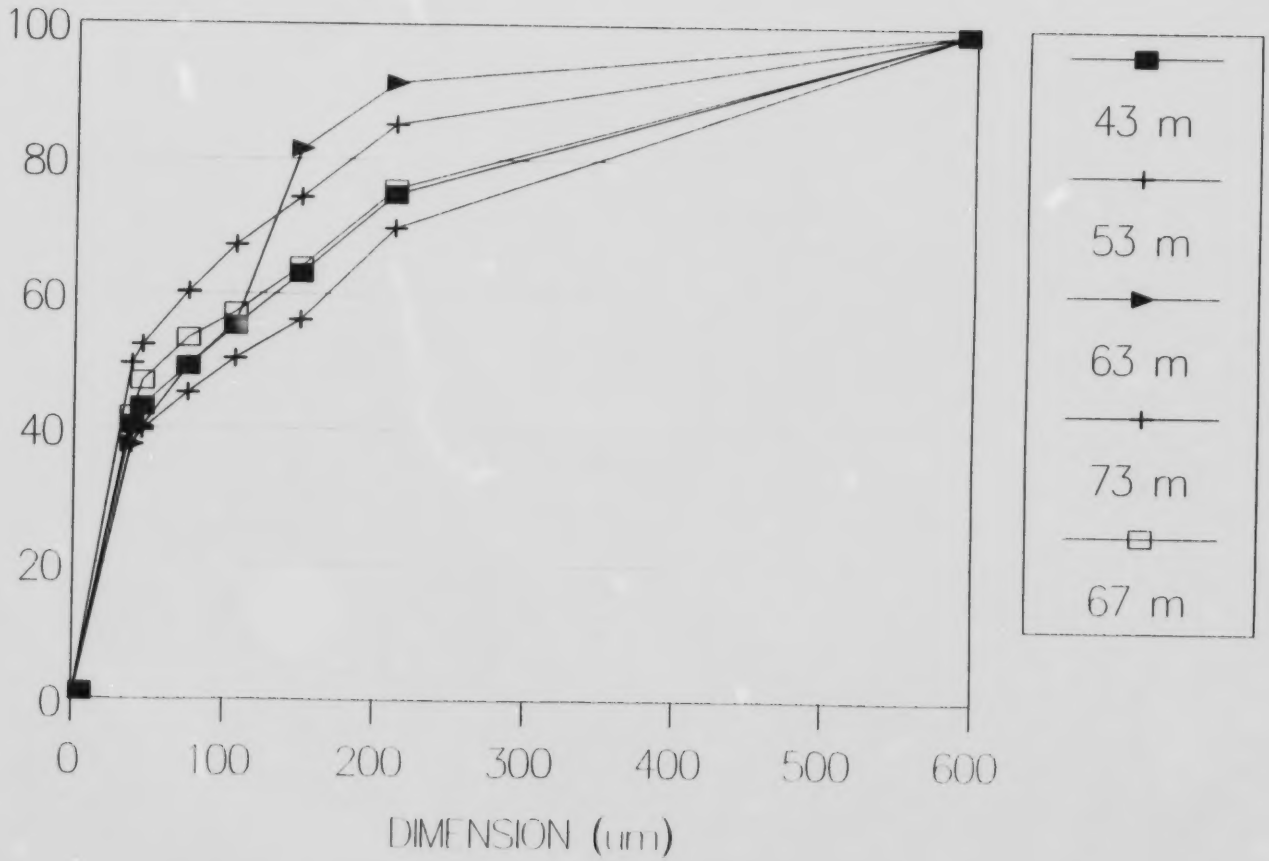


Figure 5 Graphical Representation of Collection Plate Samples (5 Oct./cut)

SIZE CLASSIFICATION

Samples 05–16

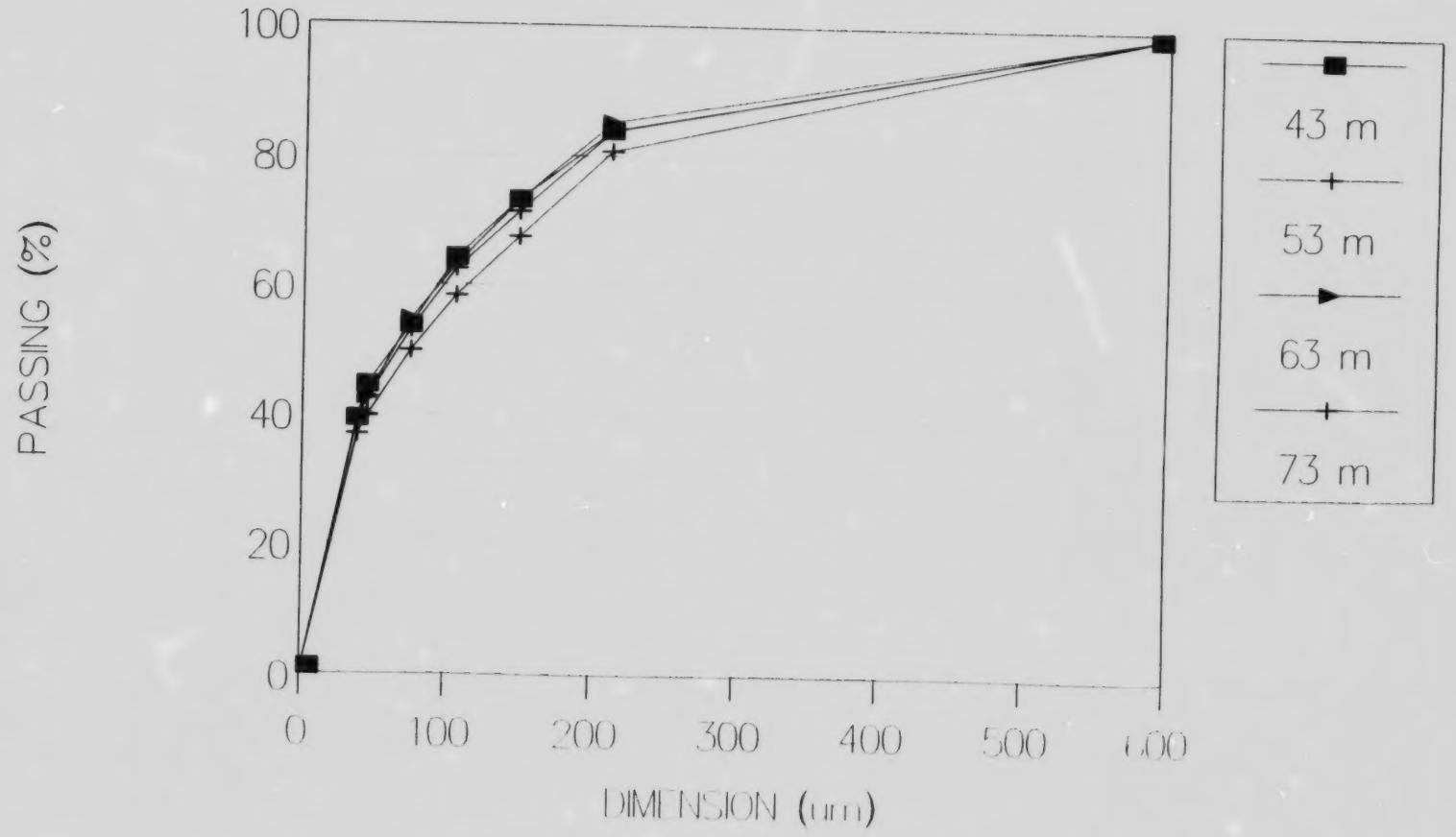


Figure 6 Graphical Representation of Collection Plate Samples (5 Oct./slash)

d) **USBM Dust Probes and RAS-II Probe**

Difficulties were experienced with the probe from the start of the test. Since the probe is a flowing system, the lenses are susceptible to dust coating. It was hoped that by applying compressed air to the lenses, it would be sufficient to keep them dust free throughout the test. However, the geology where the blasting took place was such that the dust generated heavily coated the lenses, even in the presence of compressed air. The compressed air line was also difficult to protect and was sectioned several times.

Figure 7 is an example of the voltage output from the USBM probes at various distances from the face. The sensor is sensitive to dust of -1000/1 μm and is affected by the large particle blasted forward. The spikes on the graph are caused by the rings of holes being shot at various times. The coating on the lenses is largely responsible for the drop of voltage after 5 seconds (this was confirmed by measuring the voltage once the area was cleared of dust). It is therefore impossible to use the trace as an indication of dust generation.

The Ras-II probe was more successful at measuring dust concentration. Since the dust chamber is partcially closed, problems with lense coating is greatly reduced. The Ras-II is sensitive to dust in the -10/+0.01 μm size.

Figure 8 presents the results of the Ras-II dust recorder during blasting of the second round. The recorder was attached to the back, 110 ft. from the face. Both the blast of the cut and the slash generated a maximum concentration close to 200 mg/m^3, and the concentration was still above 40 mg/m^3, 200 seconds after the blast.

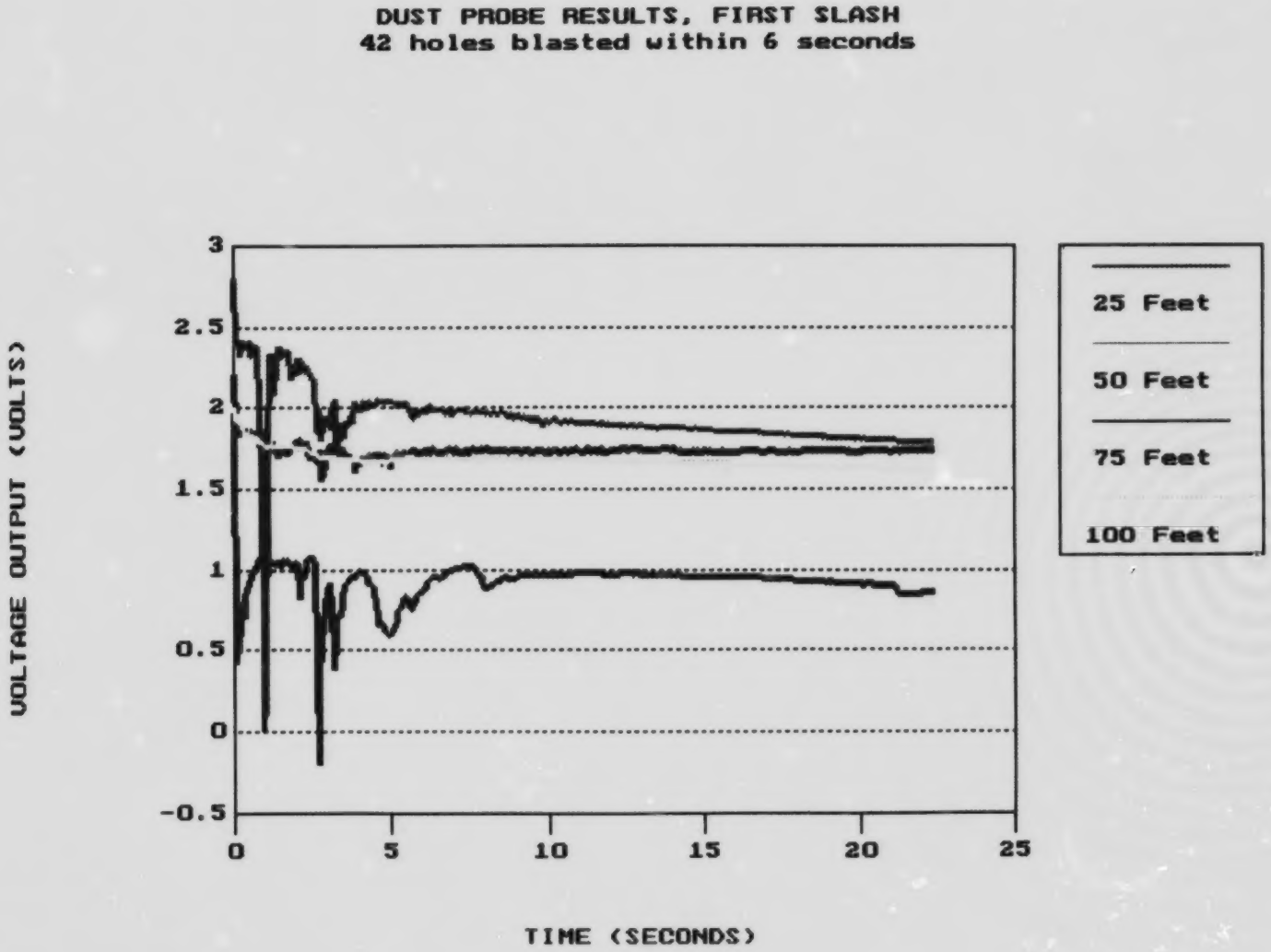


Figure 7 - USBM Dust Probe Trace

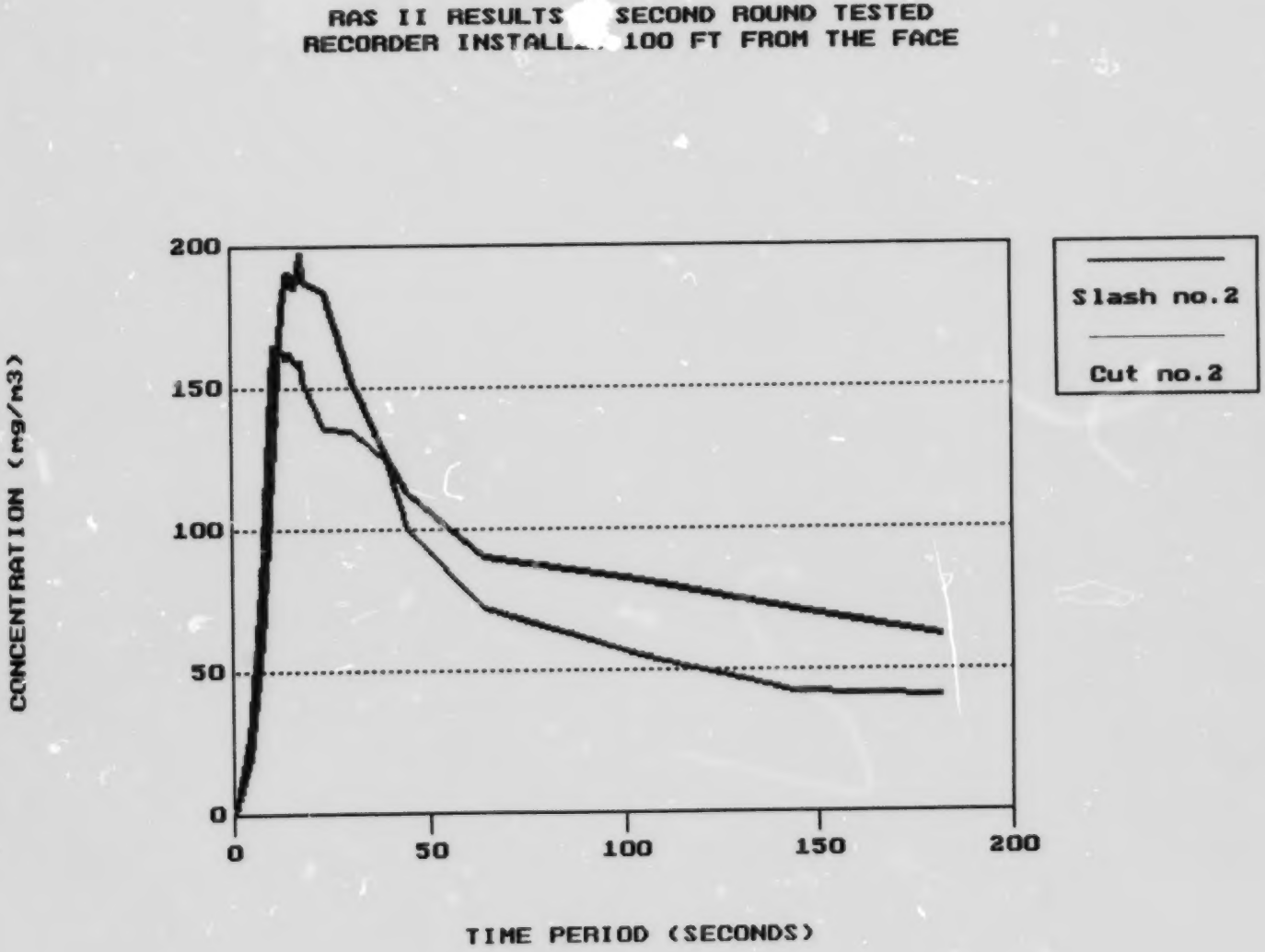


Figure 8 - RAS-II Trace for Cut and Slash No. 2

3.3.2 **Vibration Analysis**

Introduction

The waves generated by an explosion can be divided into three main categories: compressive, shear and surface as shown in Figure 9. The three main wave types can be divided into two varieties: body waves, which propagate through the body of the rock and soil, and surface waves, which are transmitted along a surface. The most important surface wave is the Raleigh. Body waves can be further subdivided into compressive or sound-like waves, denoted as P, and distortional or shear waves, denoted as S. Explosions produce predominantly body waves at small distances. Rayleigh surface waves become important at larger transmission distances.

At small distances, all three wave types will arrive together and, unlike in seismic research where the three waves will be analyzed separately, the waves are analyzed as a single pulse in this study.

To analyze the pulse, there are several types of transducers which can translate the mechanical motions to electrical signals([4]). Common ones are velocity transducers or geophones, strain gauges, displacement and acceleration transducers.

One of the most critical aspects of vibration monitoring is the mounting of the gauges in the field. The type of mounting is most critical when monitoring near a development blast. The maximum particle acceleration (can exceed 1.0 g), and the transducer can easily be dislodged. To avoid this, the transducer must be completely cemented in the rock or fastened to the rock with epoxy.

The BMX blast monitor used at BMS-M is manufactured by Blastronics Pty. of Australia. The transducer used is a common seismic transducer, or geophone. The output is generated by a coil moving through a magnetic field. The voltage induced in the coil is directly proportional to the relative velocity between the coil and the magnetic field. Figure 10 is an example of a geophone.

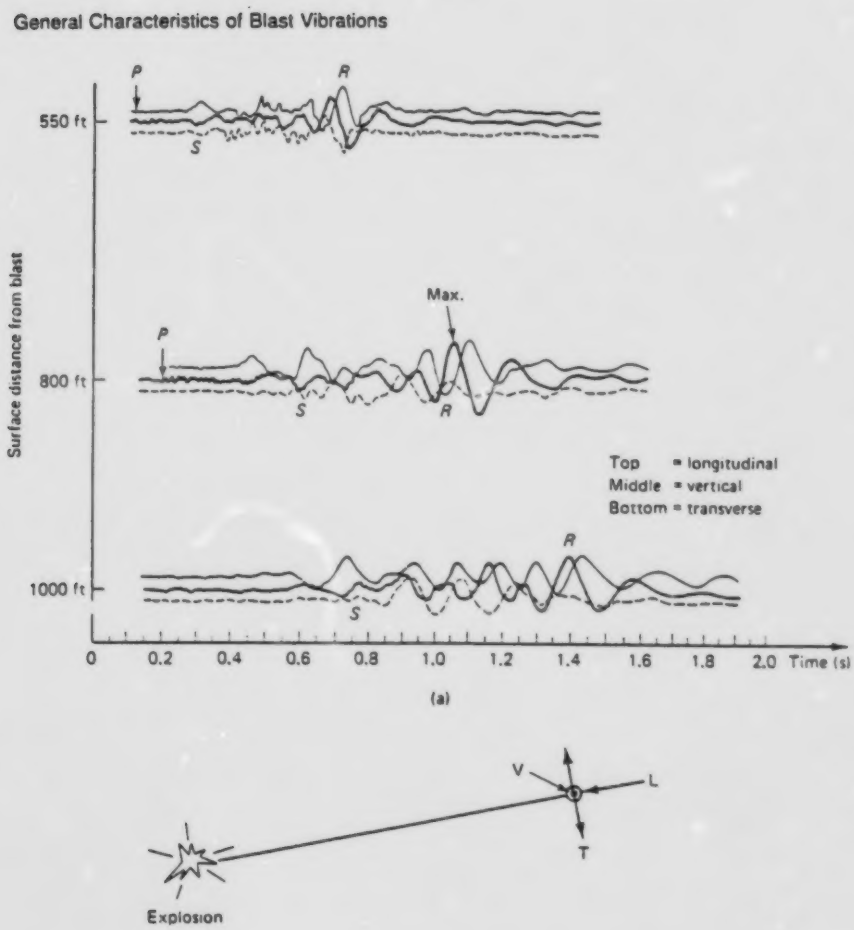


Figure 9 - Vibration Waves of an Explosion

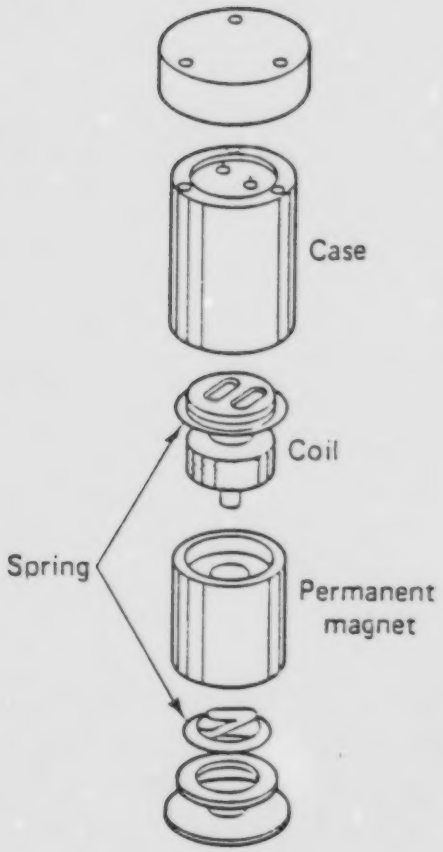


Figure 10 - Example of a Geophone

The output from the transducer is recorded by a digital recorder (64 k of memory) with a sampling rate of up to 200,000/s (200 kHz). The record is transferred to a portable PC after the blast for analysis.

Results

The vibration wave trace output from the recorder consists of a series of discrete vibration "packets", where each "packet" represents the vibration generated by an individual charge within the blast. Therefore, the first task in the analysis of this vibration wave trace is to determine which charge in the blast corresponds to each vibration packet. When all the packets have been identified, an "actual" initiation sequence can be determined, defining which charges did in fact detonate and the precise initiation times for each (+/- 5 ms).[1] Since all charges in a development blast are approximately the same size and the same distance from the vibration transducer, examining the relative amplitude of each vibration packet can also indicate information on the efficiency with which each charge has detonated.

Figures 11, 12, 13, and 14 represent the vibration record from the four blasts which were monitored. Figure 12 shows that the first burn-cut blast was not monitored properly. The transducer was probably not bonded to the rock effectively and was dislodged by the first cap going off. Tables VIII, IX and X summarizes the initiation sequence and efficiency of the blast for each test.

In examining Table VIII for the burn-cut, it can be observed that this type of cut is very inefficient. Only four holes (out of seven) performed properly. Two of the holes malfunctioned (the cap fired but did not initiate the ANFO), and one hole had a low amplitude vibration which suggests that its rock burden was too small and the explosive charge detonated inefficiently.

---

1. The analysis procedure can readily identify each delay interval, but it is not possible to identify the vibration from each individual charge on that particular delay.

EVENT FILE NAME : 575TEST

SAMPLING DATA : TOTAL TIME 13.1 secs
OPERATOR : ASHLEY JAGOE
DATE : 29-Sep-88

DETAILS :
NORANDA RESEARCH PROJECT
HELPERS ONLY

TRIGGER METHOD : Wirebreak

SENSOR
Name : TX 1 ,RAD
Sensitivity : .033
Units : volts/mm/sec
Plug# : 1
Max Recording Range : 10 mm/sec
Trigger : --

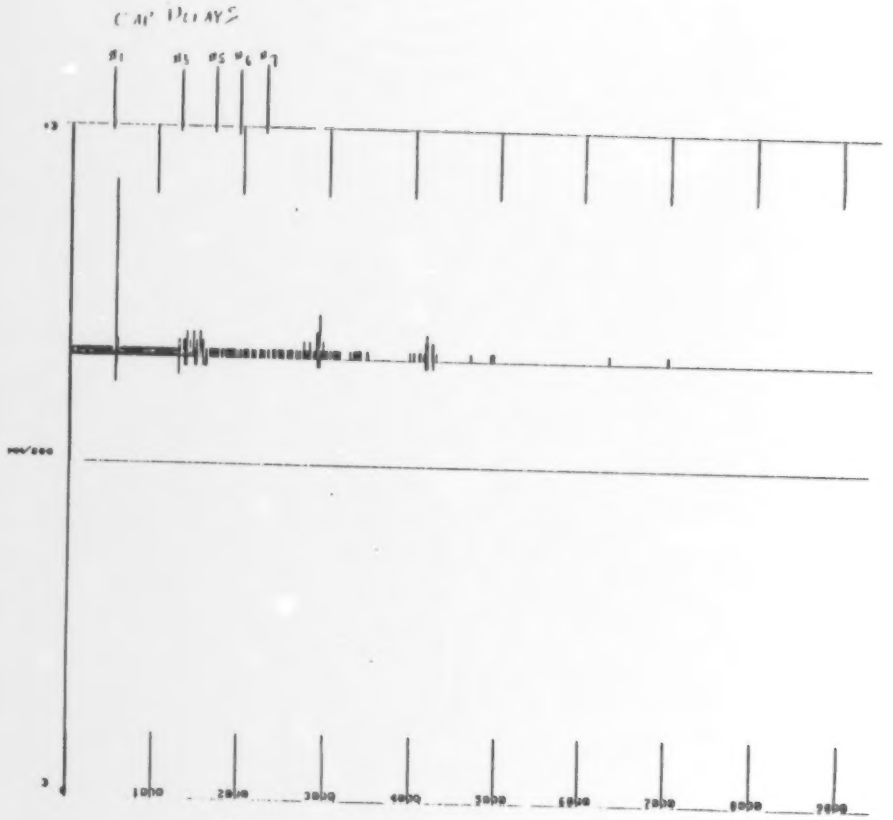


Figure 11 - Vibration Record of the First Cut

EVENT FILE NAME : 575TEST2

SAMPLING DATA : TOTAL TIME 13.1 secs
OPERATOR : ASHLEY JAGOE
DATE : 03-Oct-88

DETAILS :
NORANDA RESEARCH PROJECT
ROUND MINUS CUT AND HELPERS

TRIGGER METHOD : Wirebreak

SENSOR
Name : SURF.TRANS
Sensitivity : .033
Units : volts/mm/sec
Plug# : 1
Max Recording Range : 160 mm/sec
Trigger : --

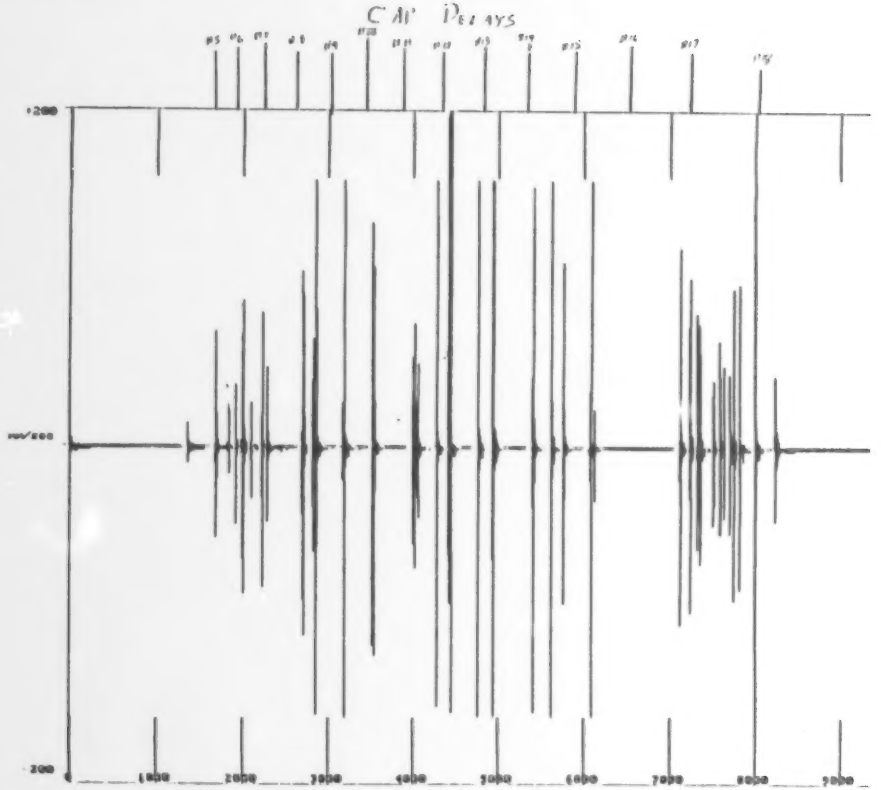


Figure 12 - Vibration Record of the First Slash

EVENT FILE NAME : 575TEST3

SAMPLING DATA : TOTAL TIME 13.1 secs
OPERATOR : ASHLEY JAGOE
DATE : 05-Oct-88

DETAILS :
NORANDA RESEARCH PROJECT
ONLY

TRIGGER METHOD : Wirebreak

SENSOR
Name : SURF.TRANS
Sensitivity : .033
Units : volts/mm/sec
Plug# : 1
Max Recording Range : 160 mm/sec
Trigger : --

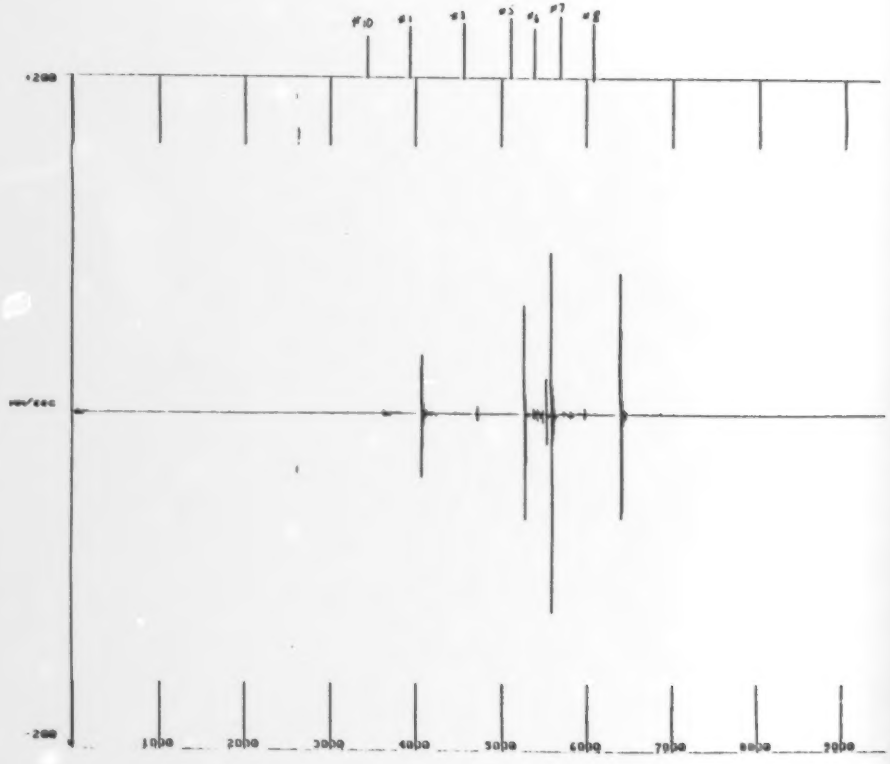


Figure 13 - Vibration Record of the Second Cut

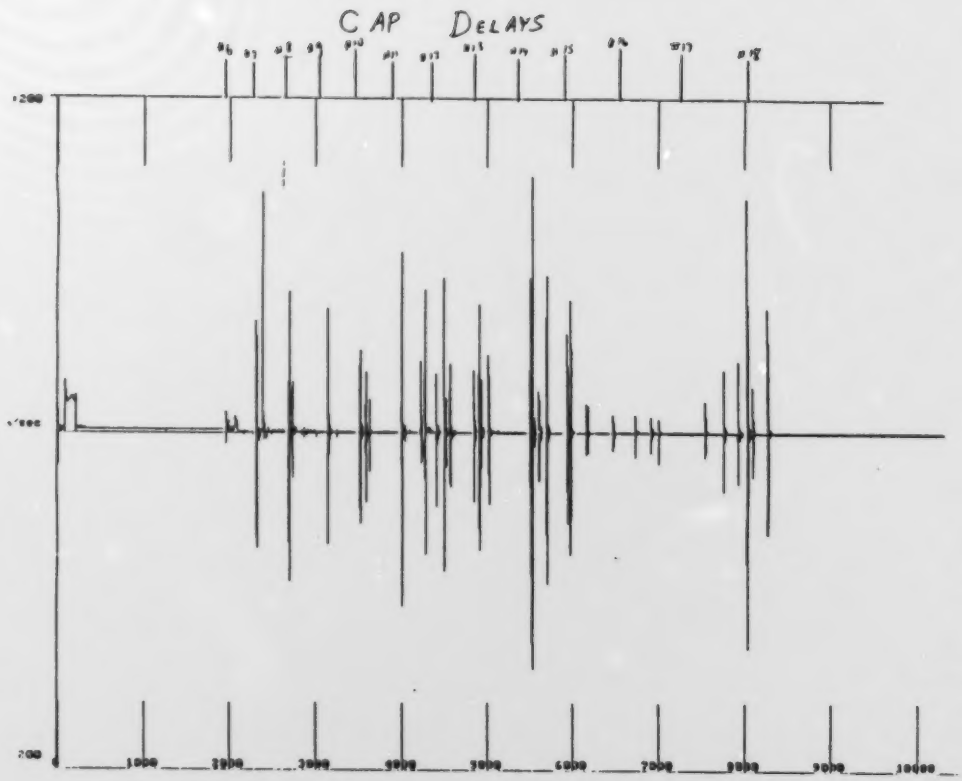


Figure 14 - Vibration Record of the Second Slash

TABLE VIII

A SUMMARY OF THE ACTUAL INITIATION SEQUENCE CALCULATED FOR ROUND No. 1 (SLASH)

Del. No.	NOM Time	Real Time	% ERR	Comment	Del. No.	NOM Time	Real Time	% ERR	Comment
5	1675	1710	2.1	OK	12	4350	4275	1.7	OK
					12	4350	4435	2.0	OK
6	1950	1850	5.1	Low Amp	12	4350	4440	2.1	OK
6	1950	1900	2.6	OK	12	4350	4440	2.1	OK
6	1950	2000	2.6	OK					
6	1950	2075	6.4	OK	13	4850	4720	2.6	OK
					13	4850	4925	1.5	OK
7	2275	2220	2.4	OK					
7	2275	2275	-	OK	14	5350	5385	0.6	OK
					14	5350	5605	4.8	OK
8	2650	2715	2.4	OK	14	5350	5720	6.9	OK
8	2650	2720	2.6	OK					
					15	5900	6100	3.4	OK
9	3050	2805	8.1	OK	15	5900	6110	3.6	Low Amp
9	3050	2825	7.3	OK					
9	3050	3165	3.8	OK	17	7250	7110	1.9	OK
9	3050	3170	3.9	Low Amp	17	7250	7220	0.4	OK
					17	7250	7320	1.0	OK
10	3450	3525	2.2	OK	17	7250	7330	1.1	OK
10	3450	3530	2.3	OK	17	7250	7495	3.4	OK
					17	7250	7550	4.1	Low Amp
11	3900	3990	2.3	OK	17	7250	7600	4.8	OK
11	3900	4000	2.6	OK	17	7250	7660	5.7	OK
11	3900	4005	2.7	Low Amp	18	8050	7700	4.3	OK
11	3900	4010	2.8	OK	18	8050	7790	3.2	OK
					18	8050	8000	0.6	OK
					18	8050	8220	2.1	OK

TABLE IX

A SUMMARY OF THE ACTUAL INITIATION SEQUENCE
CALCULATED FOR ROUND No. 2 (BURN-CUT)

Del No.	NOM Time (ms)	Real Time (ms)	% ERR	Comment
1	490	575	17.3	OK
3	1125	1300	15.6	MALF
5	1675	1790	6.9	OK
6	1950	2110	8.2	Low Amp
6	1950	2200	12.8	OK
7	2275	2510	10.3	MALF
8	2650	2940	10.9	OK

MALF = Malfunction
Low Amp = Low Amplitude Detonation
OK = Efficient Detonation

TABLE X

A SUMMARY OF THE ACTUAL INITIATION SEQUENCE CALCULATED FOR ROUND No. 2 (SLASH)

Del. No.	NOM Time	Real Time	% ERR	Comment	Del. No.	NOM Time	Real Time	% ERR	Comment
7	2275	2270	2.2	OK	13	4850	5000	3.1	OK
7	2275	2365	3.9	OK					
					14	5350	5440	1.6	OK
8	2650	2720	2.6	OK	14	5350	5445	1.7	OK
8	2650	2745	3.6	Low Amp	14	5350	5455	2.0	Low Amp
9	3450	3110	9.9	OK	15	5900	5480	7.1	Low Amp
9	3450	3200	7.2	HALF	15	5900	5535	6.2	OK
					15	5900	5900	-	OK
10	3450	3490	1.1	OK	15	5900	5925	0.4	OK
10	3450	3580	3.8	OK					
					16	6550	6130	6.4	Low Amp
11	3900	3620	7.2	Low Amp	16	6550	6160	5.9	Low Amp
11	3900	4000	2.6	OK	16	6550	6105	2.2	Low Amp
11	3900	4205	7.8	OK	16	6550	6665	1.8	Low Amp
11	3900	4245	8.8	OK					
					17	7250	6890	5.0	Low Amp
12	4350	4360	0.2	OK	17	7250	6980	3.7	Low Amp
12	4350	4465	2.6	Low Amp	17	7250	7495	3.4	Low Amp
12	4350	4475	2.9	Low Amp	17	7250	7720	6.5	OK
12	4350	4540	4.4	OK					
					18	8050	7890	1.9	OK
13	4850	4805	0.9	OK	18	8050	8000	0.6	OK
13	4850	4890	0.8	OK	18	8050	8060	0.1	OK
13	4850	4920	1.4	Low Amp	18	8050	8250	2.4	OK

While the vibration monitoring technique being described here can indicate charge malfunctions and low efficiency detonation, it cannot provide much information on the reasons for these occurrences or the mechanisms involved. However, if the reason is not because of improper loading of the explosive, wet holes, heavily fractured rock or non-parallel drill holes, the chances are it is because of overdrilling and overcharging. By overdrilling, the number of charges being used in close proximity is too high leading to interaction between charges and consequent malfunctioning of some of them.

By examining the two burn-cuts after they were shot, we observed that in both cases, one hole was still half loaded with explosive and one hole had done practically no work against the rock; it was almost intact.

The slash also contains holes which may have fired inefficiently. In the first slash (Table VIII), five holes did not fire efficiently, while in the second slash (Table X), fourteen holes did not fire efficiently and one malfunctioned. It should be pointed out, however, that the overall blast results, in terms of advance and fragmentation, was good.

Examination of the percentage error in delay accuracy indicates that the precision is poor with the delays displaying a large scatter and near cross-over between adjacent delays in a few cases. The error in delay can be probably attributed to the large pressure affecting each borehole and changing the characteristic of the pyrotechnic powders. Unfortunately, it is difficult to reduce this scatter since there are no LP caps manufactured at present which are more accurate. One way to get around this problem is to skip delays when loading, where possible, in order to have twice as much time between series of holes fired.

3.3.3 Film Analysis

High-Speed Camera

The high-speed camera takes approximately 3 seconds to get up to speed, and this was not accounted for in the first set-up. In the second test, a surface delay was installed before the blast in order the leave time for the high speed camera to get up to speed. In the fourth test, the video cord got ruptured by loose from the back, and the information was not recorded. The third test was successful.

In the beginning, the high speed camera was proposed as a tool to evaluate dust cloud generation. Unfortunately, this was impossible to achieve underground. At the high speed the camera is filming, tremendous lighting power is required to light up the face. The ELH lamps used were adequate, but they were broken right away so that the dust cloud movement could not be evaluated, and everything was blank. It is not certain that even if the light could be protected, they would penetrate the thick cloud of dust that is immediately formed when the first two holes are blasted.

The camera therefore became a more useful tool for determining flame propagation.

Still Camera

The purpose of the still camera was to determine any high intensity light formed over the period of the blast. However, the light emitted from the Nonel was so intense that it was hard to distinguish any other flame sparks through the dense dust cloud. Also, the camera required many adjustments so that, for all intent and purposes, the results were considered of little value in the study.

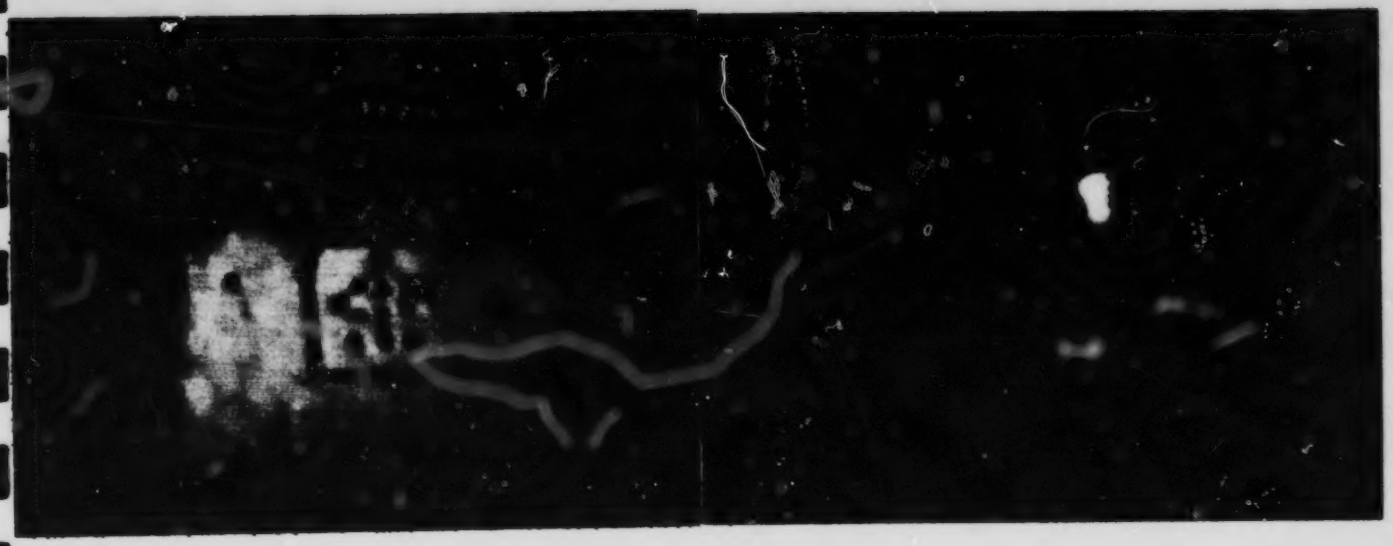


Figure 15a - No. 1 Slash Holes Configuration

Figure 15b - Flame Generation From No. 1 Slash Holes

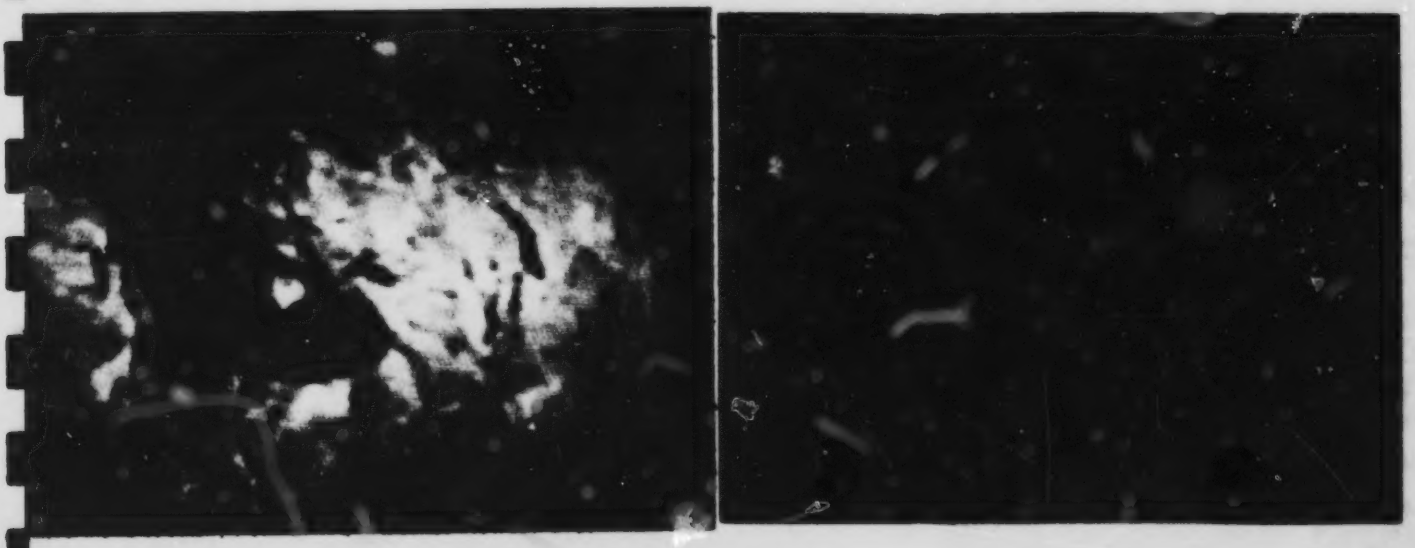


Figure 15c - No. 2 Slash Holes Configuration

Figure 15d - Flame Generation From No. 2 Slash Holes

Video Camera

The video clips of the second cut and two slashes were by far the best film results. It turned out that the slow speed of the video camera was sufficient to record flame propagation. The video clips of the blasts and the instrumentation set-up, as well as the high-speed clips, were all combined on the video presented with this report. In the cut film, it can be seen that no flame is expelled from the blast, and this is because the entire mass of rock is expelled forward, acting as a screen.

In the first slash film, intense flame is expelled from the second hole (Figure 15b). This is the hole in the first diamond, closest to the cut (Figure 15a). It is interesting to note also that this hole produced a low amplitude vibration (see Table VIII).

In the second slash, two flame spots can be seen in the upper middle section of the drift, four seconds into the blast (Figures 15c and 15d). At four seconds, two No. 12 caps (four seconds delay) are fired with a low amplitude. Two of the No. 12 caps fired are in the upper middle section of the round.

It is possible that a flame is generated in several more holes than the one observed. The dust cloud is so intense that a small flame would not be seen through the cloud. The question is whether a small flame, which cannot cut the dust cloud, can ignite the dust. This cannot be answered unless we film the actual secondary dust explosions as they occur in a drift round blast.

4. SECOND DEVELOPMENT BLASTING ANALYSIS

The purpose of the second field survey was to verify if the dust generated in sulphide rock is similar to the waste results. A high sulphide drift round on 850 mL (meter level) was chosen for the test. The round was similar in dimension to the rounds drilled for the waste tests. The drilling pattern, however, was different. Only 48 holes were drilled, and the burn-cut only contained three relief holes.

Two RAS-II dust probes were installed: one on the floor, and one on the back, forty feet from the face. After the blast samples were collected with a brush and a portable vacuum, the samples were size classified and analyzed for sulphur content.

Table XI presents the sample results and Figure 17 the RAS-II results.

TABLE XI - SIZE ANALYSIS FOR SULPHUR BLAST

Size range:	+600	-600	-425	-210	-149	-105	-75	-53	-45	-38
Brushed floor (20 ft)	4.25	10.26	19.42	8.73	10.75	11.15	9.06	8.8	5.7	22.13
% Sulphur	-	42.3	43.3	43.2	42.1	42.1	41.85	40.85	39.85	38.1
Brushed wall (20 ft)	2.86	7.98	11.01	9.25	15.86	14.29	11.58	9.47	5.5	12.2
% Sulphur	-	44.5	42.2	49.1	50.3	49.9	46.2	45.6	43.8	40.5
Vacuumed wall (20 ft)	14.03	12.67	8.16	6.03	8.76	11.24	7.81	10.11	7.12	14.1
% Sulphur	-	-	45.1	46.2	47.1	45.6	44.9	45.3	42.3	40.9

From the table, it can be seen that the sulphide rock is much more competent than the waste rock. The dust formed is not as fine as in the waste rock. The size distribution is quite even, between 0-600 μm. The waste rock breaks down into finer particle distribution which resembles flour. The density of this material is also half the density of the sulphide rock, and this is why the dust monitored with the RAS-II sensor is deposited more rapidly (Figure 16).

SULPHUR DEVELOPMENT BLAST (APP. 35% S)

48 HOLES BLASTED WITHIN 8 SECONDS

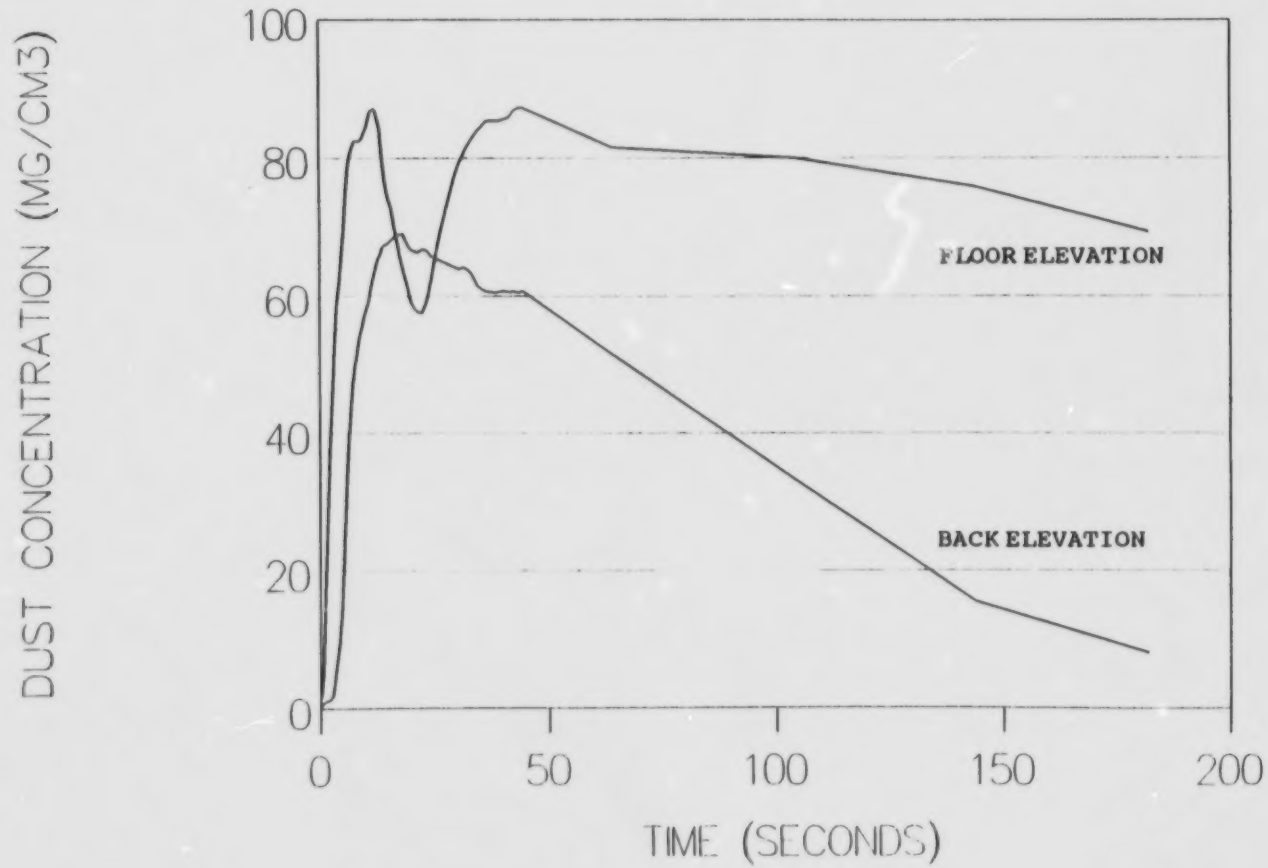


Figure 16 - RAS-II Trace for a Sulphide Blast

5. PREVENTING SECONDARY DUST EXPLOSIONS

5.1 BMS-M Fire Nozzle Technique

During the past year, BMS-M has been developing water sprays to control secondary explosions in sulphide headings. First, full jet cone spray nozzles were used. This type of nozzle is rated at approximately 4 GPM at 90 PSI. Five nozzles were used to provide a dense fog within 100 ft. of the face.

The principle behind this spraying system was to:

i) suppress the dust produced by the blast;
ii) create a water blanket to quench the flame in the event of a secondary explosion.

Early in the project, several problems occurred with the brass type nozzles. These nozzles would frequently plug up with material from the pipeline and they also had a tendency to break apart due to the handling and exposure to the blasts. Also, the nozzle had to be set close to the blast to suppress dust near the face because the spray has a very short range. This resulted in damaged nozzles. Even with these problems, the sprays were relatively successful at reducing sulphur dust blasts on the 850 m level.

In the fall of 1988, the full jet cone was replaced with PVC fire nozzles. The idea behind this application was to orient the spray directly at the cut in order to simultaneously quench the flame exiting the borehole and dampen the dust forming at the face. The fire nozzle set to fine spray used approximately 20 to 30 GPM, and only one to two were now required in the heading instead of five brass nozzles. Clogging up of the five nozzles was not a problem.

The success of using these sprays became apparent as the development crews accepted this procedure to eliminate secondary explosions in their headings without hesitation. The sprays were generally set up within 12 ft. of the face, secured to a rockbolt with a piece of wire.

Water Consumption

In conjunction with developing water sprays, the BMS-M training department's attention turned to developing a timer activated valve to control the water flow. Assuming the sprays were opened at 11:45 P.M. and closed at 2:30 A.M., the sprays would have been on for 165 minutes. This would result in the following consumption:

165 x 25 GPM = 4,125 gallons

Although the sprays were very effective in controlling sulphur blasts, water consumption was increased dramatically. This was especially true towards the end of January 1989 when this method was introduced on the 1000 m level also. The next phase of the project had to do with reducing the water volume required for this control.

To calculate the value of water used in the underground operation, this value can be used:

$50,000/GPM/YR or $0.10/GPM/MIN

The goal was to control the sprays for a total spray time of 5 minutes:

5MIN * 25 GPM = 125 gallons

This would result in a savings of approximately 4,000 gallons of water:

5MIN * .10 = $400.

To be effective, a spray timer system had to respect the following considerations:

1) Unit had to be battery powered to simplify hook-up and relocating.
2) The unit had to be portable.
3) Operation of the system had to be simple, all connections to water line and blast line kept as simple as possible.

4) The system had to be safe - the method of hooking up to the blast for triggering to be inherently safe to avoid complications or controversy.

A timer was built and tested in the field based on the above design criteria. Six timer systems have been designed to date, and they have been well received by the mining crews. The design of the fire nozzle and timer system is described in a report to management by D. Gagnon of BMS-M. The report is presented in Appendix G.

5.2 Optimization of Blast Pattern

Most of the work in controlling development sulphide blasts has been focused on developing methods to reduce or dilute the dust (foggers, lime) and quench the flame (water or water gel cartridges). The work carried out in this project raises the possibility of controlling the secondary blast through optimization of the development drilling pattern, delay sequence and explosive type.

Present long period delays used in development blasting creates the worst possible conditions for secondary blast. The dust from each successive hole has ample time to disperse itself at the face before the following set of holes are fired. Ideally, a delay of 5-10 minutes should be allowed between the burn cut and the auxiliary holes, and the auxiliary holes and the perimeter holes. Such delays would ensure that the dust generated by the burn cut is all settled before blasting any other boreholes.

Practically, however, this is not possible. When the rock is blasted, the fragments are expelled from the face in every direction and any blast initiating wires extruding from the holes may be severed. It is therefore impossible to obtain the required delay with a sequential blasting machine or a safety fuse. Each cap will have to be burning inside the holes from time zero. To place a delay of 5-10 minutes after the cut will require having caps manufactured with 5-10 minute delays. Standard chemical caps have a delay inaccuracy of 5% or greater. A 10-minute delay cap would have a precision of +/- 30 s. This is unacceptable. Electronic igniters could provide the required accuracy, but they are only at the experimental stage, and it could be a few years before they are commercially distributed.

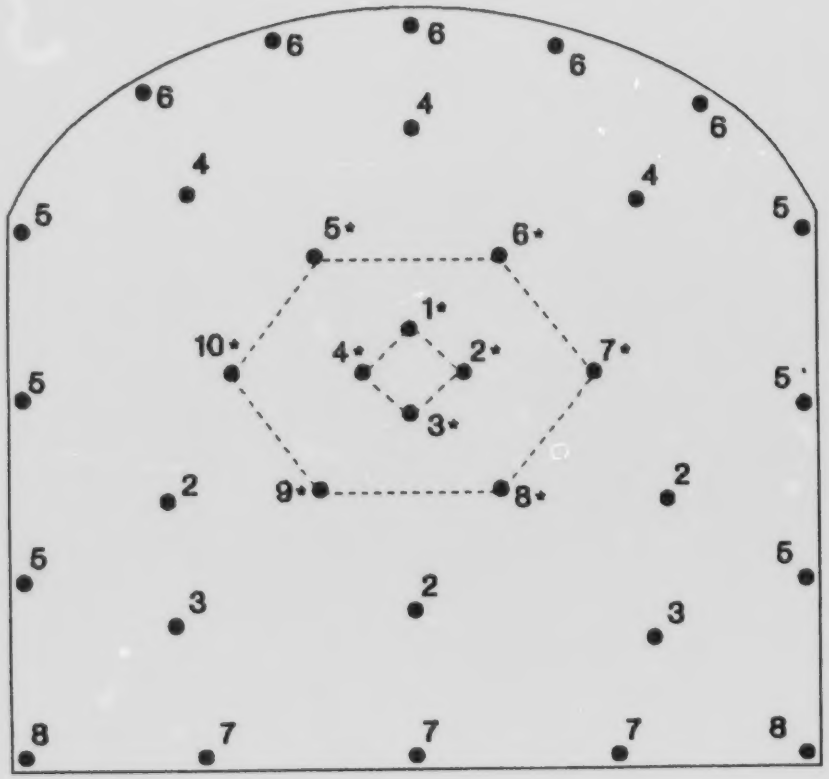
Since it is not possible to make the delays longer, perhaps the best solution is to reduce the delay time. By reducing the delay time sufficiently, it could be possible to stop the dust from dispersing sufficiently between each set of holes fired. The primary concern with decreasing the delay sequence of the round is plugging or freezing of the burn cut. All blasting manufacturers recommend using long delay periods to allow sufficient time between successive holes.

The Julius Kruttschnitt Mineral Research Centre (JKMRC) of the University of Queensland, Australia, have done extensive field work in development blasting in 1986-87, under the Advance Blasting Technology project sponsored through The Australian Mineral Industries Research Association (AMIRA). Their research showed that most development rounds are overloaded and, as a consequence, 10% of holes can misfire or fail to detonate completely.

JKMRC developed a corkscrew burn cut design which is fired with millisecond (MS) caps and does not require easer holes (see Figure 17). In a traditional burn cut, empty relief holes provide space for rock swelling after the first holes are fired. By using MS caps, the swelling or gas propagation through the fractured rock will only occur after all shots of the burn cut are fired. The use of easer holes becomes useless for the relief of all the burn cut rock mass and is therefore not required anymore. In all JKMRC trials, the burn cut was always pulled out to its full depth, and fragmentation was good. By using the cut developed by JKMRC, it is possible to reduce the blasting duration from 8 to 3 seconds. This would considerably reduce the dust/flame contact time.

Furthermore, the JKMRC rounds are also optimized in terms of number of holes drilled in order to reduce interaction between charges. Malfunction of charges can be due to an "overcharging" problem where the number of charges being used in close proximity is too high, leading to physical interactions between the charges, and the consequent malfunctioning of some of them. This same mechanism can also be used to explain the low efficiency detonation of some charges, in that where the level of charge interaction is relatively minor, charges may detonate at a lower efficiency rather than completely malfunctioning. (We believe that a low

The JKMRC 34 holes burn-cut



All Holes charged

Holes Diameter 1 3/4"

1* MS Delays

2 LP Delays

Figure 17 - JKMRC Corkscrew Burn Cut

efficiency detonation due to overloading and reduced burden could be responsible for the flame propagation). A reduction in the interaction between holes would, in this case, reduce the flame propagation.

5.3 SO_2 Mine Re-entry System

An early SO_2 warning system is highly recommended in sulphide mines to detect and locate sulphide dust explosions in advance of men re-entering the mine. The system, if well designed, will also provide information on the efficiency of control methods and the risk associated with different mining zones.

The 3ST electrochemical cell tested under this project is suitable to be used as the sensor device in the monitoring system. The 3SF cell is not required, as we are only interested in the 0-100 ppm range.

Many manufacturers now build their sensor around the 3ST cell. Once important criterion when choosing a manufacturer is to verify that the electronic circuitry used in amplifying the signal is of very high quality to reduce noise pick-up and drift sensitivity. Examples of reliable manufacturers are Sieger and J. Jones of England. The sensors are priced at approximately $1,000 (see Appendix C: City Technology Based Sensor Manufacturers).

In a warning system, the sensors should be installed in the exhaust raises where the volume is not more than 150,000 CFM. This is important because the instruments are precise to approximately 2 ppm. Since most development drifts and stopes are supplied with 25,000 CFM of fresh air, the concentration in the exhaust at 150,000 CFM will be diluted six times. The sensor will therefore only respond to a sulphur blast producing a concentration of 12 ppm, and this appears to be approximately the minimum concentration of a secondary blast.

For example, in a mine like Brunswick where a million CFM of air is supplied to their main production levels, seven sensors will be required.

The critical part of such a system is the communication and power link. Since the sensors are in the exhaust, there will be no close source of power supply. A good alternative will be to link the SO_2 sensors with a two-wire current loop cable which will provide both power and communication to the sensor. This type of cable has a capacity of 1 km, but can be boosted. Appendix D describes a system by Electromatic which is suitable. There are also other systems which will work (e.g.: Action Inst., Conspec, etc...). The cost of such a system for seven sensors would be approximately $15,000, excluding the cost of the software and portable computer, as well as the cost of running the wire through the mine. If the mine is equipped with a programmable logic controller on every level with available 4-20 Ma ports, a simple shielded two-wire current loop could also be run directly to the sensor.

The software can be purchased off the shelf at a cost of $4,000 to $7,000, and can be configured to update the user every 15-30 minutes. The console should be installed in the shaft station where it can be attended at at all times after the end of the shift blast.

The sensors will require almost all of the maintenance to the system. The cells will have to be calibrated for zero drift every three weeks and for span drift every two months. They will have to be replaced every two years.

6. CONCLUSIONS AND RECOMMENDATIONS

CONCLUSIONS

The data obtained from this project help to understand how a secondary explosion is formed during development blasting in sulphides. New possibilities for reducing risk have been identified.

In a development blast, the blasting of the cut produces as much dust as all the rest of the round. This dust probably cannot be ignited by the cut itself because of the material moving out. Sixty five percent of the dust produced is greater than 500 μm, and this dust is deposited within one second according to the USBM dust probe trace. The -600 μm dust stays suspended for several seconds and accumulates after each hole is fired. In soft schists, 40% of the -600 μm dust is in the -38 μm size and, because of the low density of the material, the concentration can reach 1000 mg/m^3 (500 mg/m^3 from the cut and 500 gm/m^3 generated from the slash) at the face. In sulphide material, the rock is more brittle and also more dense. The -38 μm size only makes up 10-18% of the total weight of the -600 μm dust and the total cumulative concentration is probably reduced (~400 mg/m^3) because of the reduced amount of dust generated and the faster deposition.

Therefore, during a secondary dust explosion, it can be assumed that the dust near the hole, which is the igniter source, is at a concentration of 300-400 mg/m^3 and is composed of well-graded particle sizes between 0.1 and 600 μm.

It was also observed during the test that an intense flame front which could cut through the dense dust cloud is produced sporadically. In comparing the flame generation with the vibration analysis, it appeared that the flame could be associated with a low efficiency detonation where the rock burden is insufficient to absorb all the energy released by the ANFO.

To reduce secondary explosions, two methods are proposed. Both are based on the observation that the burn-cut produces tremendous dust and the assumption that the burn-cut and first diamond ring tend to be overcharged, causing the diamond ring holes to detonate inefficiently and generate an excessive flame.

The first method, which was proposed by BMS-M, is to direct a fire nozzle directly at the cut in order to suppress the dust quickly and possibly quench the flame from the diamond ring holes.

The second method, which is proposed by NTC, is to re-design the blasting pattern in order to minimize cross-interaction between holes and eliminate low efficiency deflagration of explosive. Also, patterns should maximize the use of available explosive energy to breaking rock. This will hopefully eliminate excessive flame propagation and also have the added benefit of reducing the number of drill holes and explosive used. Figure 18 illustrates the difference between an optimized and non-optimized round.

SO_2 Monitoring

The electrochemical cells in the 0-25 ppm range manufactured by City Technology have been found to be sufficiently accurate for early warning of underground secondary sulphide dust explosions. However, no tests were done to verify the cell life. The manufacturer claims that the cell life is around 1-2 years (depending on SO_2 concentration).

Manufacturers of complete sensors (the cell and the conditioning hardware are packaged in a single box) designed for underground use are presented in Appendix C. They can be provided with a standard 2-wires 4-20 ma output. The mine can therefore hook them to the PLC network they have at their site.

The sensors should be installed in the return airways of each level. The airways chosen should not exceed 100,000 CFM. At this volume, the air supplied to the dead-end drift (usually 15-30,000 CFM) will not be diluted more than six times. This is important since the minimum concentration that can be detected by a sensor is ~2 ppm, and a secondary explosion in a dead-end drift can produce as little as 10-15 ppm of SO_2.

Figure 18 - Non-Optimized vs Optimized Development Blast Pattern

RECOMMENDATIONS

A. **In-Mine Practices**

1. Utilize SO_2 units to monitor for secondary ignitions before re-entry. (The SO_2 system still needs some development for continuous operation).

2. Based on BMS-M successful practice:

   - Install fire nozzle near the face and direct the flow towards the cut. Use timing system to reduce water usage.
   - Turn off auxiliary fan upon leaving a loaded drift round to confine suspended dust distribution.

3. Other key recommendations:

   - Wash down the walls before each drift round blast.
   - Stem all the holes with inert stemming or water cartridges (leave collar of one foot whether stemming or not).
   - Return unused caps to the magazine.
   - Do not blast in two adjacent headings simultaneously.

FUTURE RESEARCH WORK

1. Investigate blast development optimization techniques in order to reduce flame and minimize flame/dust contact.

2. For production blasts, investigate the efficiency of slurries and emulsions as replacement products for ANFO. These explosives have shown to produce less flame in large-scale tests conducted by the USBM([1]).

REFERENCES

1. Minutes of the Sulphide Dust Explosion Control Group, Montreal, 13 June 1989.

2. Hall, A.E., Mchaina, D.M., and Botsford, J.D. Sulphide Dust Explosion Studies at H-W Mine of Westmin Resources Limited. Proceedings of the 4th Vs Mine Ventilation Symposium, University of California, 5-7 June 1989.

3. Koplin, H. Carbon monoxide and nitrous gas content in the fumes of commercial explosives during short firing tests in a rock chamber. Nobel Heft., October-December 1979, Vol. 45, No. 4, p. 129-156.

4. Garcia., M.M., and Malcomson, M.. Gases from explosives detonated in underground mines. Bureau of Mines OFR25-27, NTIS No. PB87-1911805/AS, June 1986.

5. Floyd C. Bossard and Associates Inc. A Manual of Mine Ventilation Design Practices, 2nd ed., 1983.

6. Dowding, C.H. Blast vibration monitoring and control. Prentice-Hall Intl. Series in Civil Eng. and Eng. Mechanics, 1985.

APPENDIX A

IN-MINE EVALUATION WITH THE UNIVERSITY OF BRITISH COLUMBIA

IN-MINE EVALUATION OF SULPHUR DIOXIDE SENSORS

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DEPARTMENT OF MINING AND MINERAL PROCESS ENGINEERING

DECEMBER 20, 1988

Abstract

The University of British Columbia, Department of Mining and Mineral Process Engineering (MMPE) evaluated two SO_2 sensors by measuring their response to sulphur dioxide during an underground production blast. Both sensors, type 3ST designed to measure 0-25 ppm, and type 3SF for 0-2000 ppm are made in the United Kingdom by City Technology Limited. The objective of this investigation was to evaluate, select and define the present state of the art for SO_2 detection monitors.

The sensors were evaluated at the H-W mine of Westmin Resources Limited, Campbell River, British Columbia. The results of the field testing are given in this report.

The span, zero drift and stability for all sensors were quite impressive. The 3ST sensor was found to have 0.9% of full-scale drift for span and 0.5% of full-scale drift for zero readings while the 3SF sensor showed 1.1% of full-scale drift for span readings. Field testing of the sensors showed that they are dependable and accurate.

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The authors wish to thank Westmin Resources management for giving permission to conduct the experimental work on their property. The assistance and cooperation of Mr Peter Schultz, chief mine engineer; Mr Dave Botsford, senior mine engineer; and Mr Jim Hartle, training coordinator throughout the investigation are greatly appreciated. In particular, we are most grateful to Mr Siegfried Rohr for his very practical assistance in organizing underground visits and conducting the field work.

The views expressed here are the authors' and do not necessarily reflect Westmin Resources opinions.

1.0 INTRODUCTION

This report describes the results and conclusions of an investigation under a Noranda Research Centre contract for a project entitled " Evaluation of Dust and SO_2 Generation by Blasting of Sulphide Ores". The objectives were to evaluate, select and define the state of the art for SO_2 detection monitors.

During blasting of massive sulphide ores, dust clouds can be created and ignited, resulting in a secondary explosion which releases considerable volumes of sulphur dioxide. High SO_2 concentrations are a risk to people and cause production delays until they are cleared from the mine.

Noranda Research Centre proposed the work to be conducted either at the H-W mine of Westmin Resources or the Ruttan mine of Hudson Bay Mining and Smelting Co. Ltd. Westmin Resources was selected because of its easy access to University of British Columbia project personnel. The following qualifications were also considered in obtaining an appropriate test mine site:-

i) Sulphide dust ignition history for the mine.
ii) Explosion - prone high sulphur ore deposits being mined.
iii) Management interest.

Westmin Resources had all the above qualifications and in addition the management expressed high interest and commitment in the investigation.

The selected test area was the exhaust air from mining production blasts in K330 stope.

Two type 3ST and two type 3SF sensors were evaluated. The stability test examined each sensor's ability to maintain its initial zero and span settings over a sampling period. All four sensors were found to be reliable and can survive rugged underground mine conditions.

In addition, the literature relating to the following SO_2 monitoring techniques was reviewed:-

i) Non dispersive infrared.
ii) Infrared.
iii) Fluorescence.
iv) Semi-conductor.
v) Electrochemical.

2.0 EXPERIMENTAL DESIGN AND TEST PROCEDURES

2.1 INSTRUMENTATION

Four SO_2 sensors manufactured by City Technology Limited were used for the in-mine test work. These were type 3ST for trace readings of up to 25 ppm and type 3SF for readings of up to 2000 ppm for high gas concentration analysis. These sensors are of the three-electrode type and the change in potential of the sensing electrode on exposure to SO_2 gives a signal which is proportional to concentration.
The basic sulphur dioxide monitoring system, consists of a sulphur dioxide sensor and a digital data logger. The sensor unit provides an instantaneous analog output signal between 0 and 1 Volts. The 1 Volt signal is equivalent to 25 ppm or 2000 ppm concentration depending on the concentration range of the sensor. The sensors' specifications are given in Appendix A.

All the data from the monitors was simultaneously recorded on two 4 channel data loggers for precise analyses.
The analyzers - types 3ST and 3SF had reaction times of less than 45 seconds. Problems encountered with these monitors during the project were: lack of zero setting for the type 3SF sensor, and the time taken to fully charge the battery pack was too long. The problems were not corrected but were reported to the project contractor. Daily calibrations were performed, before air sampling, with Matheson zero gas and Matheson certified SO_2 span gases (16.9 $\pm$ 0.3 ppm and 1546 $\pm$ 30 ppm).

A Draeger polymeter was used for the determination of the mean value of gas concentrations in air over the sampling period. Special draeger long-term detector tubes were used. The volume of air drawn in is about 15 cm^3 per minute, calculated in the following manner:

$V[cm^3] = (N_1-N_0) \times K.$
Where, K = hose constant = 0.75 cm^3/rev, N_0 and N_1 are initial and last counter indications.
The detector tube is located inside the instrument in such a way that it is protected from external flying objects by a cover. This permits its use in areas subject to explosive sulphide ignitions, without damage.

All sensors were positioned in the return side of the blast area at about 60 metres from the blast extremities. This was approximately 30 metres behind the water foggers.
Most of the experimental stations for the in-mine test work were located on the 2300 level in K330 stope. There were only three active panels during the time of investigation, (7, 8 and 9). One more test was conducted on 2400 level while blasting 350 long hole stope.
Figures 1 and 2 show the sampling stations for both experimental locations.

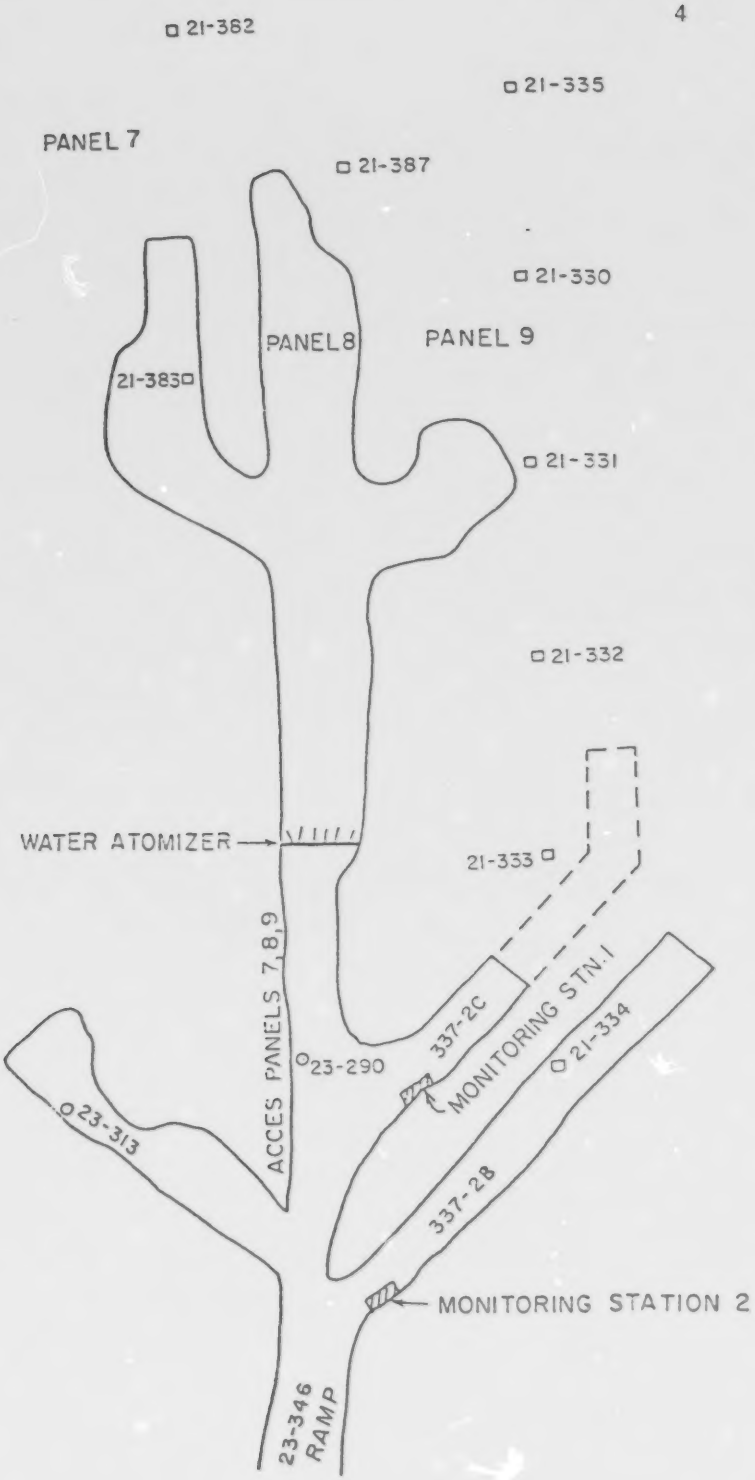


Figure.1 K 330 Stope Layout

JULY 1988

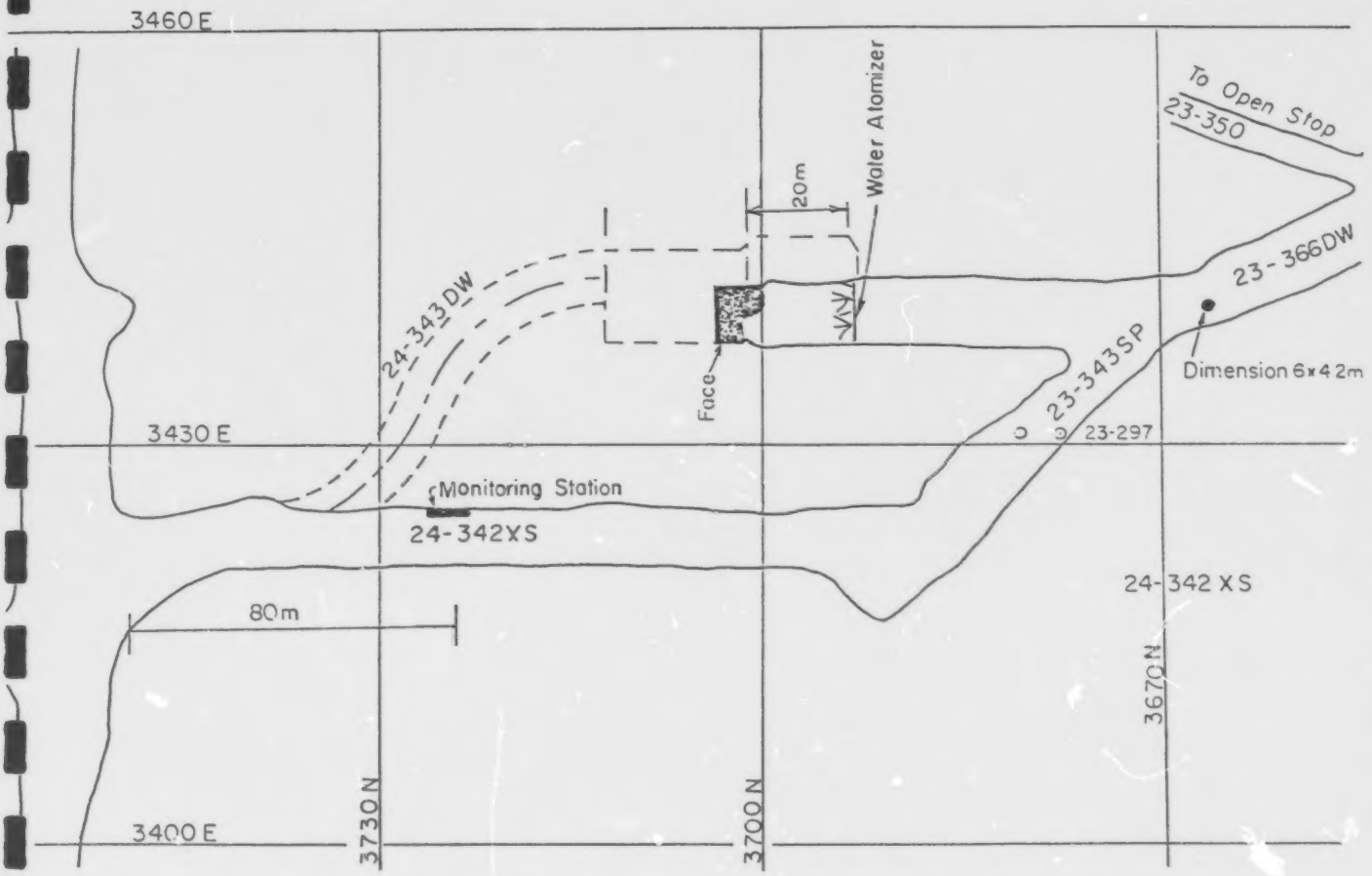


Figure. 2 23-343 Sumps Locality Plan

NTS.

2.2 TEST PROCEDURES

The procedure which was followed for each blasting experiment was as follows:

i) Zero and calibrate SO_2 instruments on proper range.
ii) Mount instruments firmly.
iii) Record mine temperature, barometric pressure, and relative humidity.
iv) Get loading, explosive and sulphide dust ignition control and preventative data for the round from miners.
v) Check water atomizers and ventilation for proper operation.
vi) Switch on the instruments and check if they are properly set.
vii) Leave with mine operating crew at end of shift.
viii) Remain on surface during blasting.
ix) Allow 15 minutes for the fumes to clear before returning underground.
x) Wear gas mask, go in, pick up data, and turn off instruments and polymeter pump.

Generally, it took about 20 minutes to calibrate the instruments and set the data loggers.

2.3 H-W MINE

The H-W Mine of Westmin Resources Limited, is a highly mechanised operation of about 4000 tonnes per day production. The mine employs three main mining methods to recover the ore:

i) Long hole,
ii) Cut and fill, and
iii) Room and pillar stoping methods.

2.3.1 Blast Design

In long hole stoping, the drill pattern of vertical holes is 1.52 x 1.52 metres and the length of the holes averages 15 to 21.5 metres. In other production stopes using cut and fill and room and pillar methods, the drill pattern when breasting or benching is 1 metre X 1 metre and 4 metres deep. The backholes are drilled with a lesser burden than 1 metre and additional lighter explosives are used in those holes to control fragmentation. The drill pattern, when silling a production stope is similar to the drill pattern in a development operation, where rounds are drilled and blasted. The most successful cut, used at the H.W. mine is the shatter cut, consisting of 5 holes: 4 reamed holes, each 76 mm diameter and drilled in a square pattern 200 mm apart. The fifth hole is a standard 82 mm diameter blasthole, drilled in the center of the square and acts as the free face for the cut blast. Four helpers and four diamond holes aid in the breaking of the cut. After the cut has been blasted, the pattern follows a 1 metre X 1 metre pattern, with less than 1 metre burden for the perimeter holes. Figure 3 shows a blast design for a typical shatter cut blast at the H-W mine.

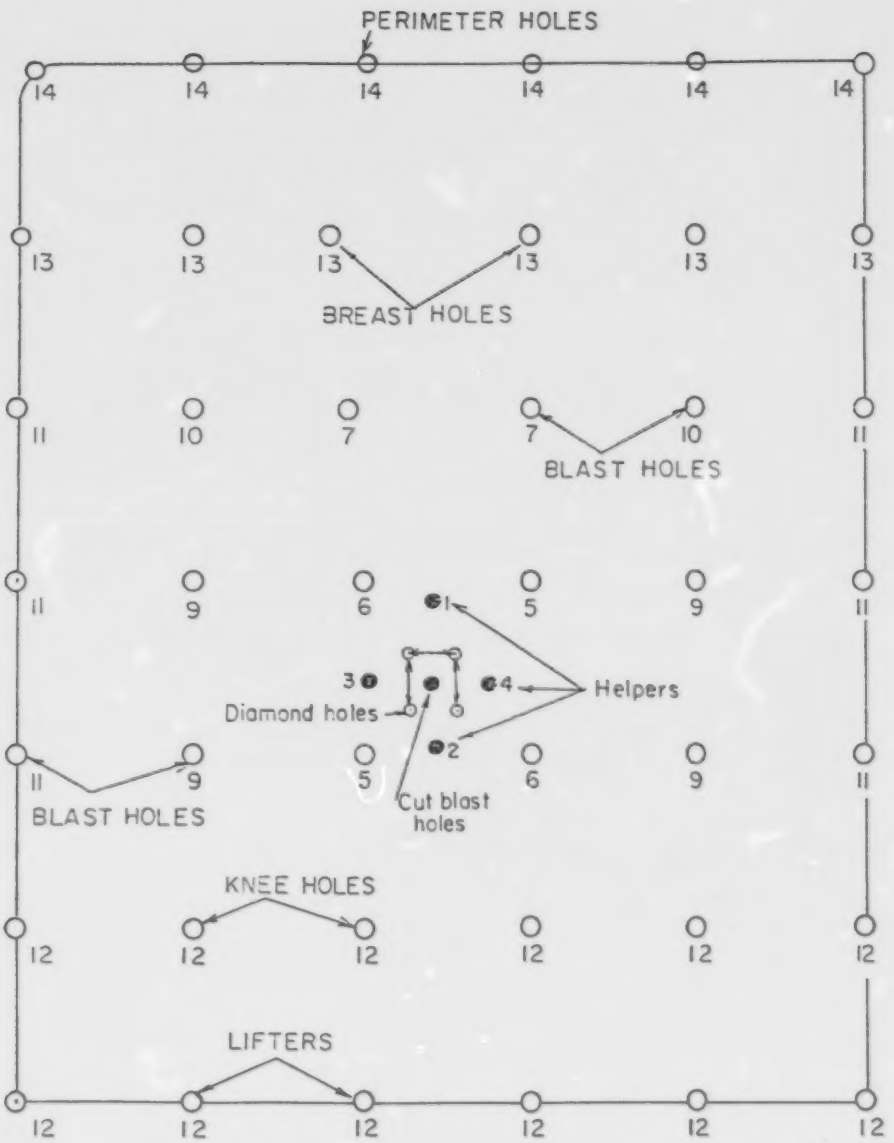


Figure. 3 Typical Blast Design -(K 330 Stope)

2.3.2 Types of Explosives Used

The following explosives are used at the H-W mine:-

1. Amex II: manufactured by C.I.L; a free flowing plant mix of ammonium nitrate prills and diesel oil.
2. Cilgel 70%: A nitro glycerin based explosive mostly used as a primer or in wet holes.
3. Tovex 2000: A water gelatin explosive.
4. Tovex BL 4032: Replaces Tovex 2000.
5. Tovex Sakpak: Used for secondary blasting.

(Tovex products are manufactured by E.T.I.)

5. Magnafrac: An emulsion explosive.
6. Magnapak: Used for secondary blasting.
7. Trimtex: Water gelatin explosive, used for perimeter blasting.
8. B-Line: Detonating cord used with nonel detonators.
9. Primer cord: A detonating cord with twice the strength of B-Line used in long hole blasting operations.

2.3.3 Detonators

1. XT Nonel long delay: 4 meter length, 0-15 delay used in production and development headings.
2. BX Cap short delay: 5 metre length, used in long stope blasting - 0-15 delay.
3. Electric Blasting Caps: Used to initiate blast with either B-Line or primer cord. Also used to blast down hang-ups in chutes or mill holes.

3.0 SULPHIDE DUST IGNITION PREVENTION AND CONTROL PRACTICES

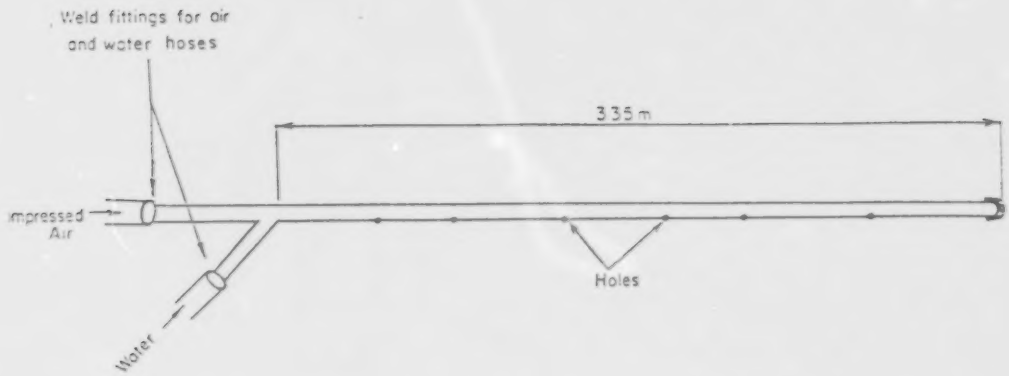
The following preventative techniques are employed in varying combinations prior to blasting to prevent secondary dust ignitions:

i) Washing of walls, floors and backs up to 100 metres from the face;
ii) Concurrent blasting of lime bags;
iii) Water atomizers/foggers;
iv) Stemming of blastholes with water and lime catridges;
v) Clearing the area of all combustible material before blasting;
vi) Centralized blasting; and
vii) Good ventilation flow to help the foggers to atomize.

Some safety measures such as evacuation of men from the mine prior to blasting and keeping miners in underground refuge bays have also proved to be effective.

3.1 STOPE WATER ATOMIZER

Figure 4 shows a water/air spraying system used at the H-W mine. The 25.4 mm diameter steel pipe has six holes drilled into it, with a hole diameter of 2 mm giving a flow rate of about 3.50 litres of water per hour. The water fogger is turned on one hour before blasting in order to atomize the stope. The water atomizer is located between 15 and 45 metres from the face. Throughout the study the water atomizer was located at about 30 metres from the face.



SPECIFICATIONS

1. 1" STEEL PIPE
2. HOLE DIAMETER 5/64 ≈ 2 mm

Figure. 4 Details of Water Atomizer

4.0 STATISTICAL DESIGN OF EXPERIMENT

4.1 SOURCES OF ERROR

Like most experimental work, there were many sources of error. These include:

i) Observational (human) errors associated with reading the data and scale limitations in recording measurements.

ii) Instrument errors associated with the sensors and support equipment such as the data loggers used to obtain the SO_2 measurements.

iii) Errors due to pressure and temperature gradients.

Pressure and temperature gradients resulting from the explosion or blast concussion affected the sensor reading because these affect the accuracy of diffusion sensors. Observational errors were minimized by rechecking all data. Data was extracted from the logger twice in order to check for the missed values. Another way to minimize this type of error was to transfer stored readings to a computer. The data transfer program (SQLOT3) sent to the subcontractor was not compatible with the PC's used by the Mining Engineering Department at the H-W mine. Instrument errors were minimized by calibrating the sensors with a calibration gas before each measurement.

5.0 EXPERIMENTAL RESULTS

5.1 FIELD DATA

The output from each instrument was directly and continuously recorded as a function of time by two four channel data loggers. In all cases concentration measurements were recorded as the fraction of full scale volts output.

Mine temperature, pressure and relative humidity before and after each experiment are shown in Table 1.

Table 1. Mine Environmental Conditions

	Before Blasting	After Blasting
Temperature (^{o}C)	17.0 ± 1.00	19.0 ± 0.00
Relative Humidity (%)	90.0 ± 2.00	100.00
Barometric Pressure(KPa)	104.69	-

Table 2 gives results of the long term calibration and zero drift and stability test conducted at the temperatures and relative humidity as shown in Table 1.

Table 2. Long-Term Calibration and Zero Drift and Stability

Range (ppm)	Span Gas	Span			Drift	Zero		Drift	
		Initial	Mean	High	Low	Init.	Mean	High	Low
0-25*	16.9±0.3	0.675	0.674	0.679	0.67	0.0	0.003	0.005	0.0
0-2000	1546	0.770	0.772	0.775	0.764	-	-	-	-

* Conducted at ambient temperature 17.0±1.00 ^{o}C, R.H. = 90.0±2.00%

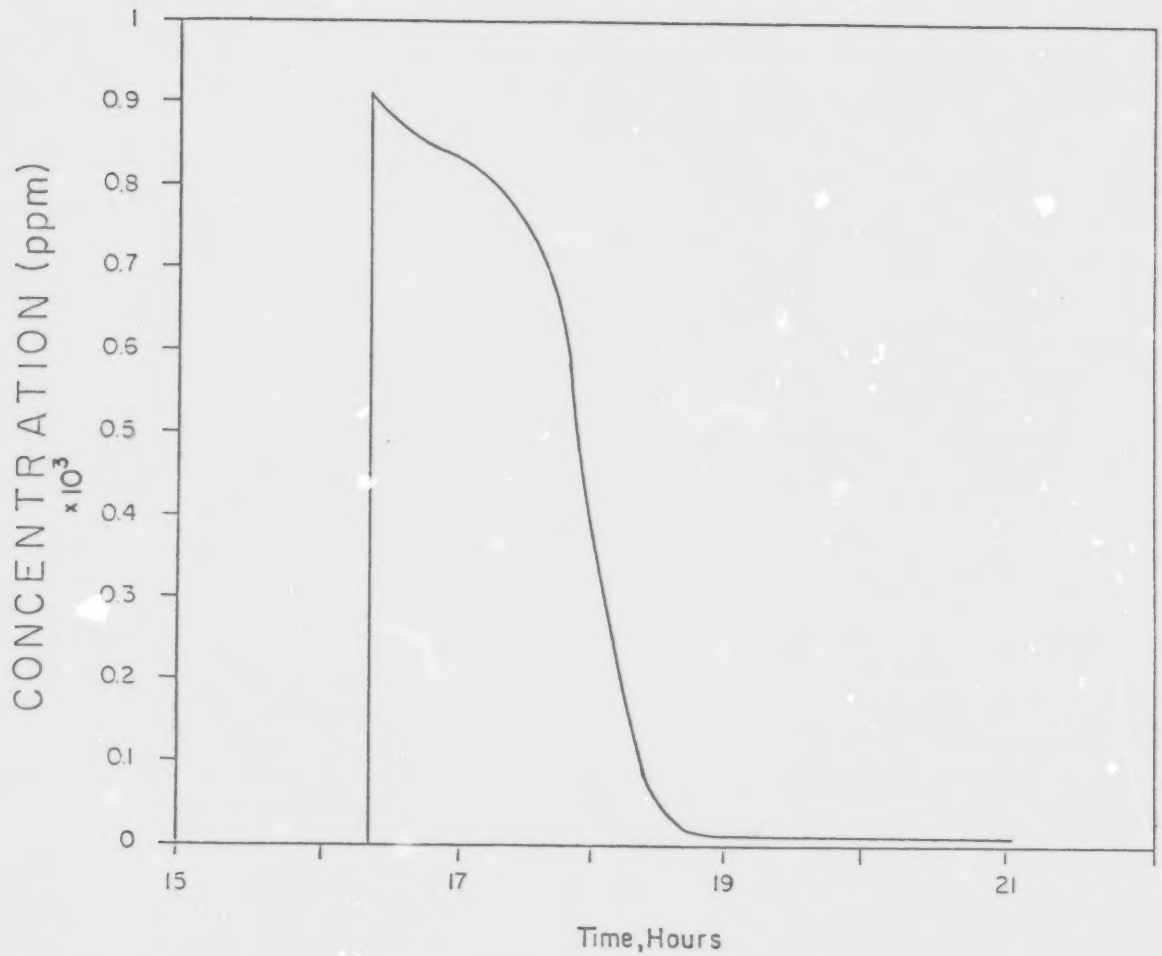


Figure. 5 Stope K330 - SO_2 Concentration

Panels 7 And 9 - 18/07/88

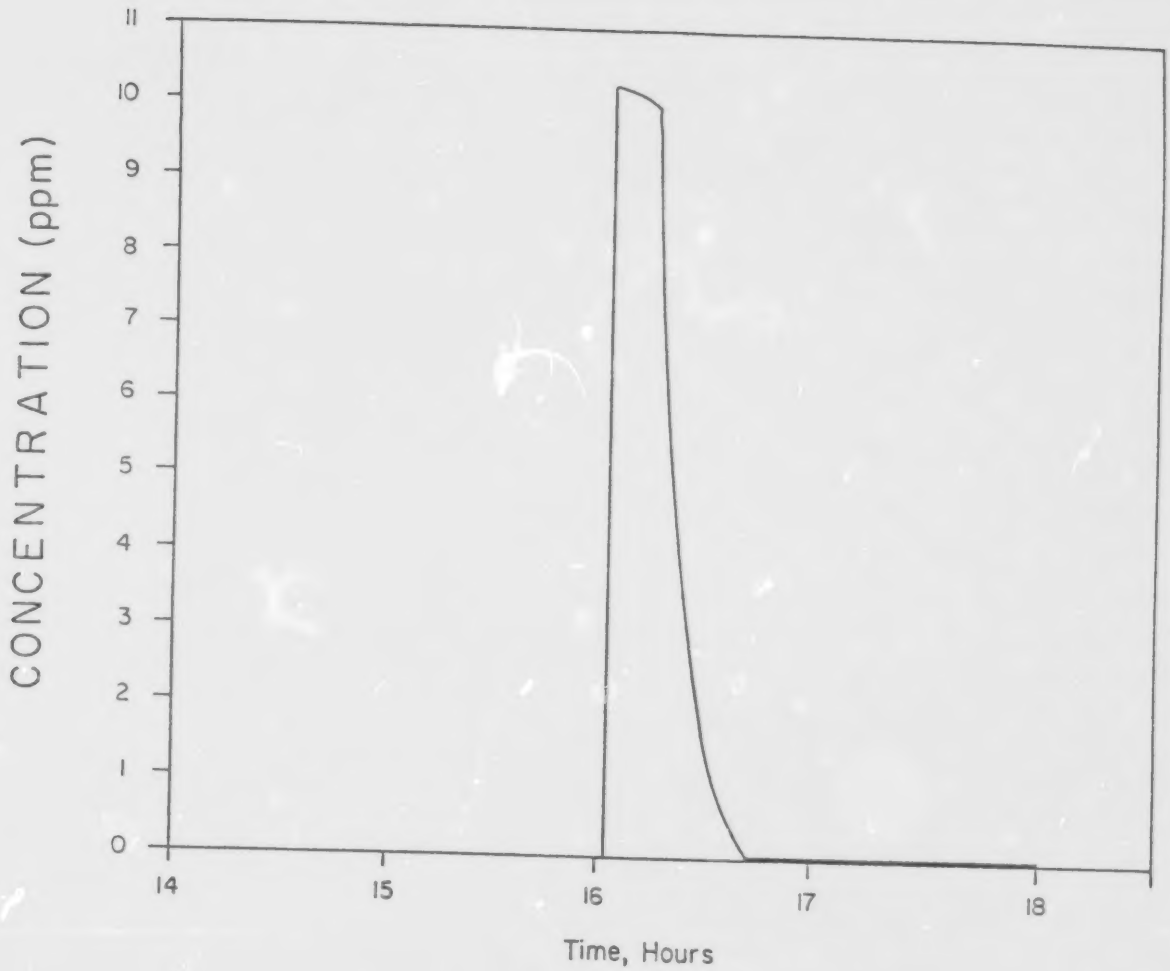


Figure .6 343 Sump – SO_2 Concentration

SO2 Source = 350 Open Stope - 20/07/88

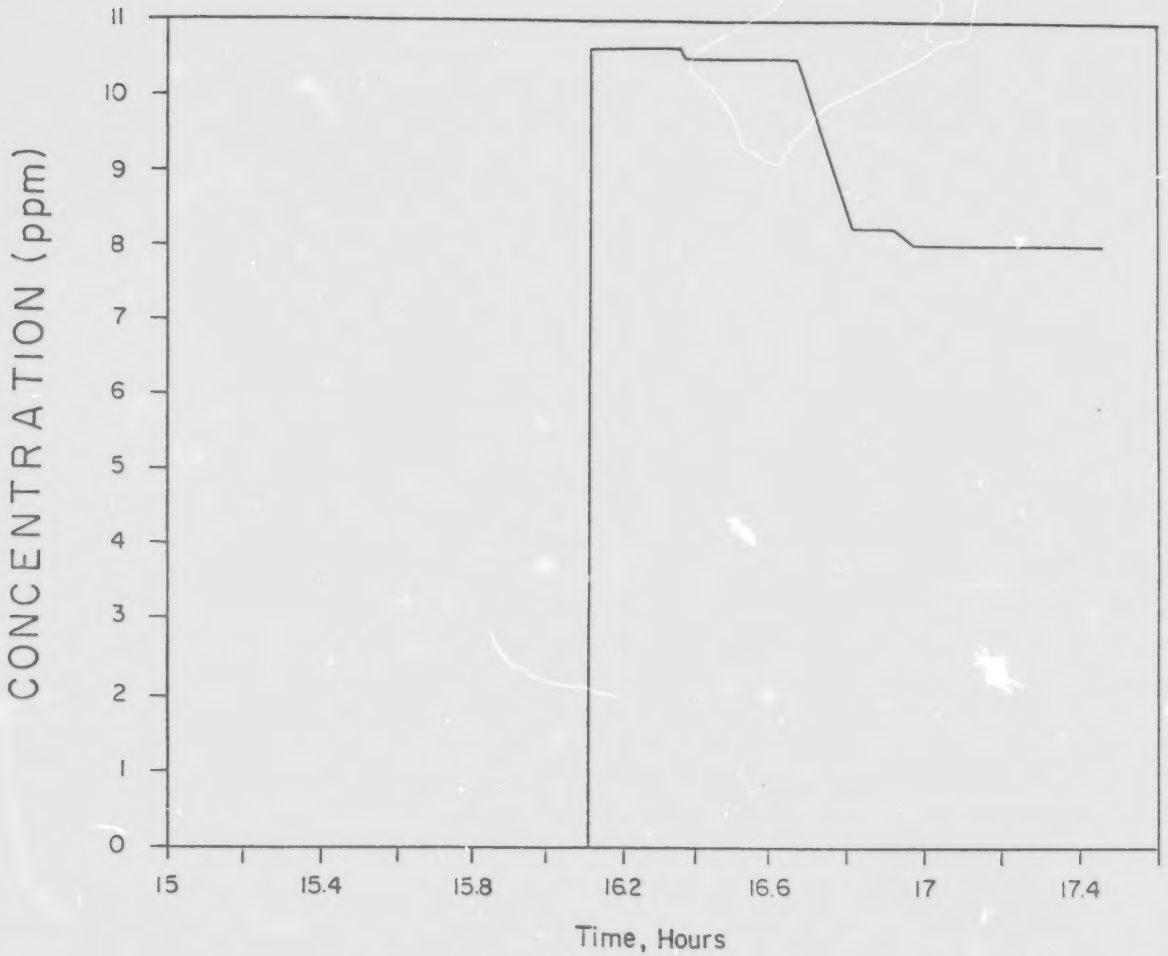


Figure. 7 Stope 330 - SO_2 Concentration

Panel 9 And K 337-2C-21/07/88

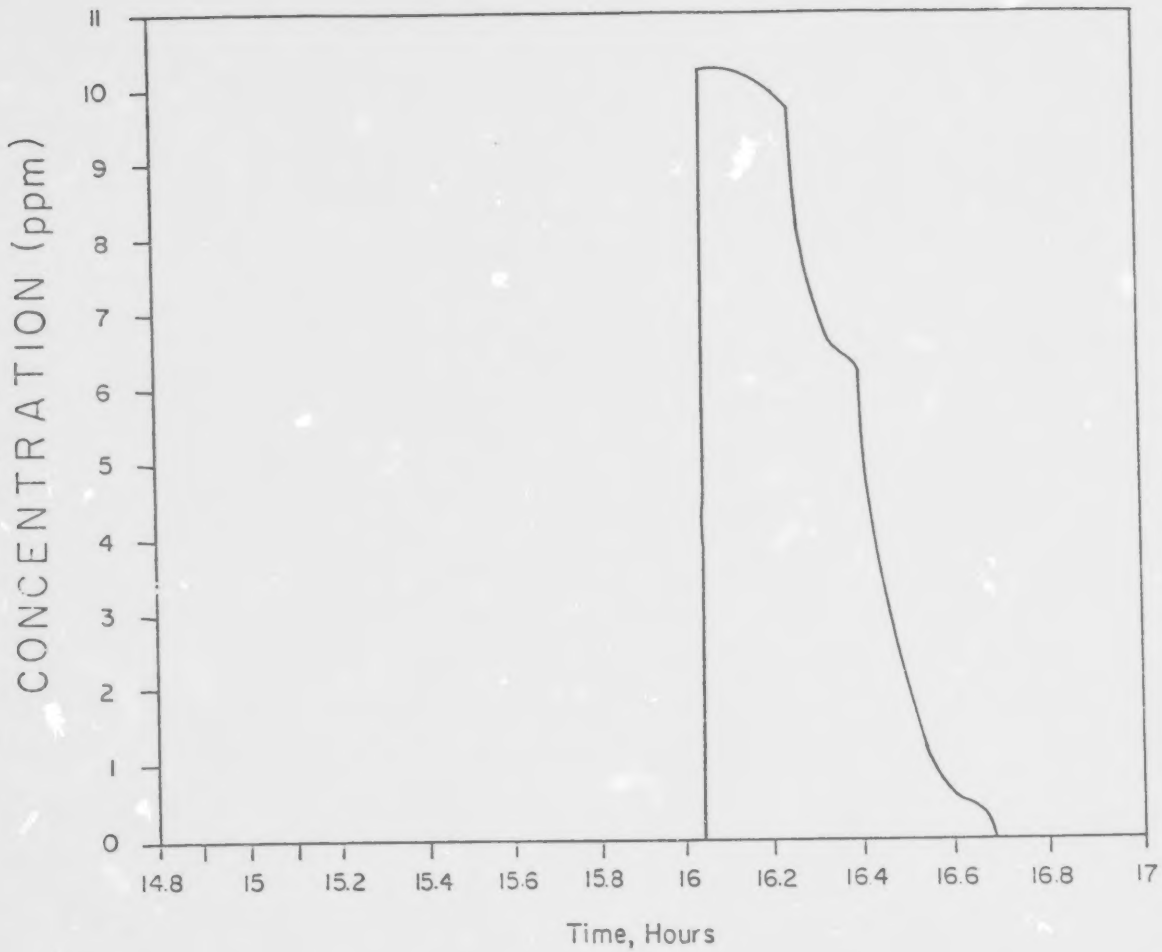


Figure.8 Stope K330 - SO_2 Concentration

Panel 9 And K337-2C 21/07/88

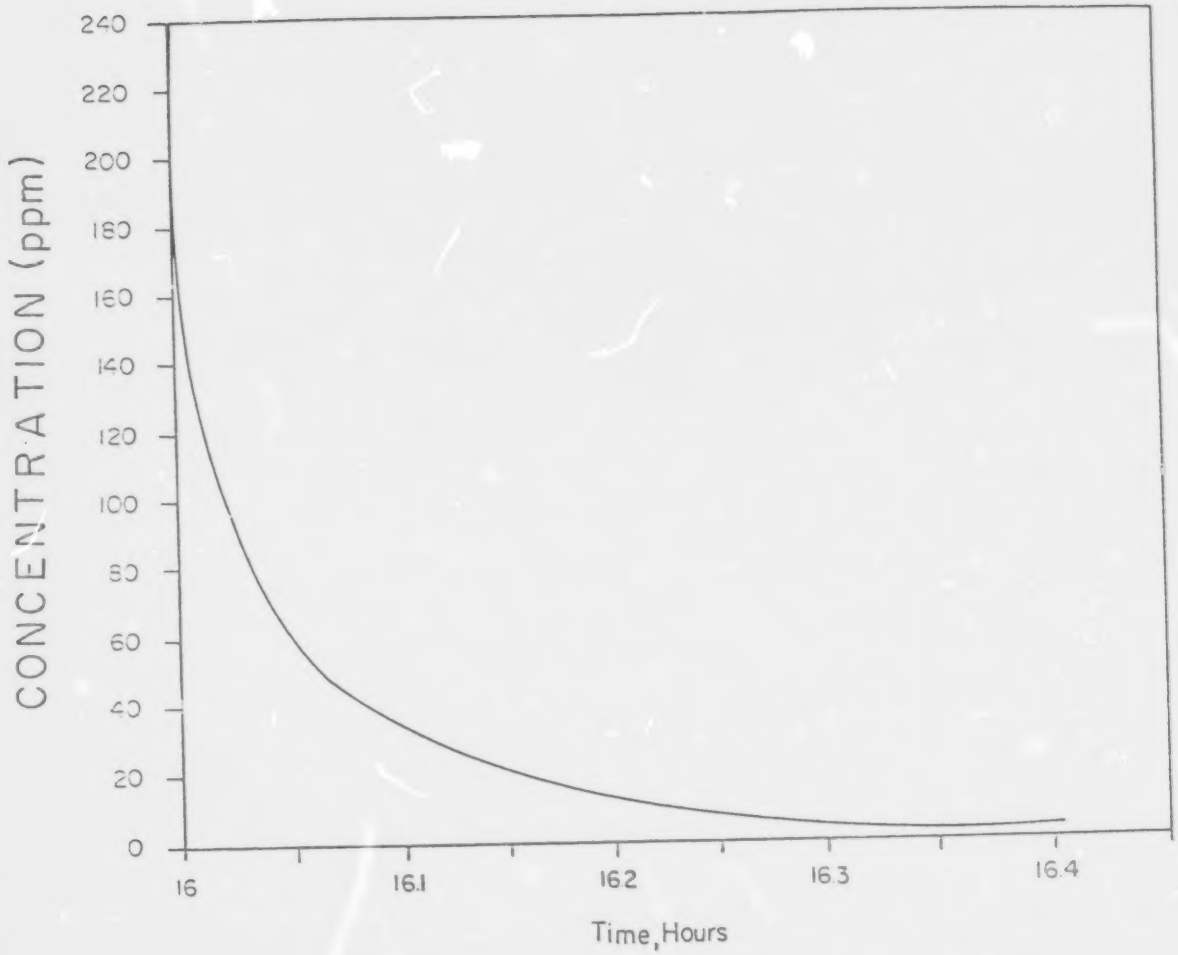


Figure. 9 Stope K330 - SO_2 Concentration

31/05/88

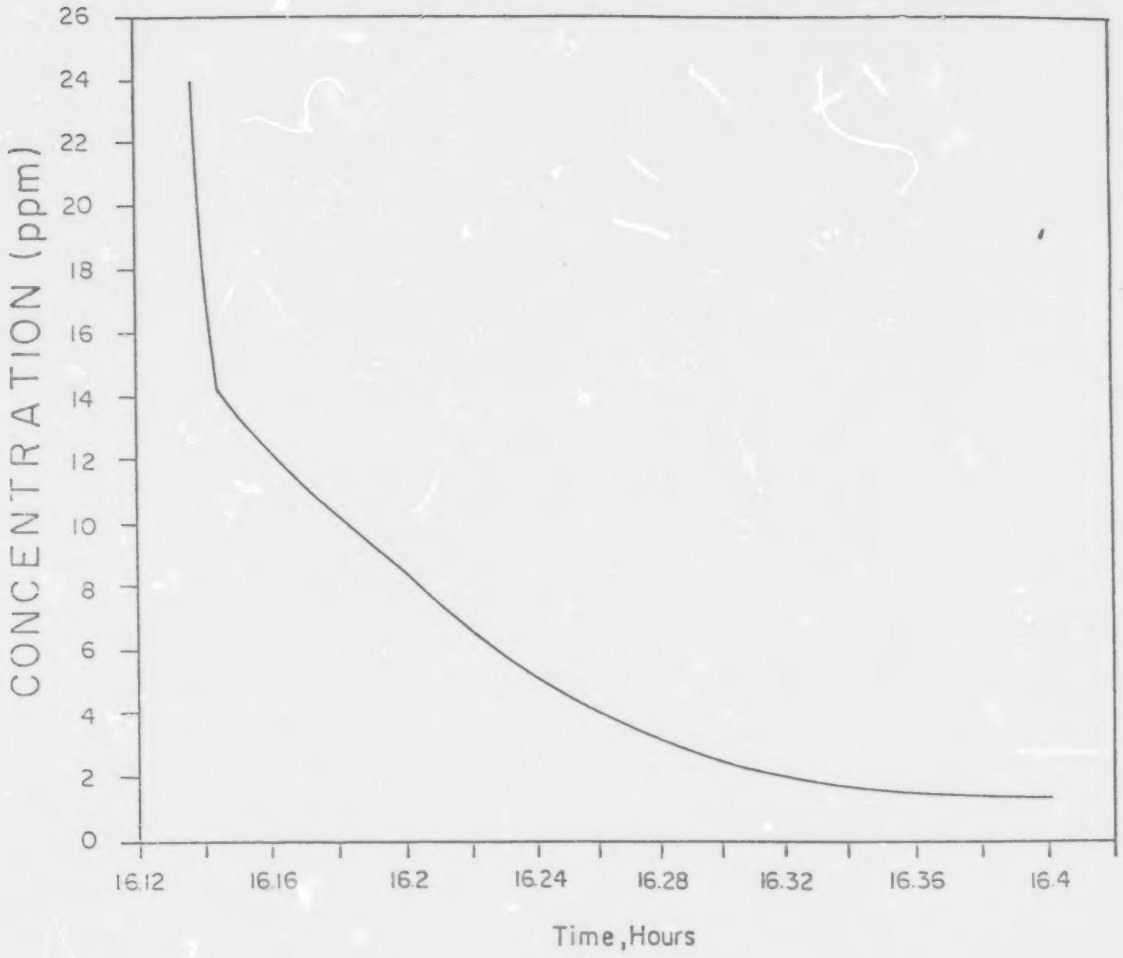


Figure. 10 Stope K 330 – SO_2 Concentration

31/05/88

The span, and stability for both sensors are impressive, as is the zero drift for the 3ST sensor, as shown in Table 3.

Table 3 Maximum Deviation in Span and Zero

Range (ppm)	Calibration Parameters (v)		As Percentage of Full Scale	
0-25	Span 0.009	Zero 0.005	Span 0.9%	Zero 0.5%
0-2000	0.011	N/A	1.1%	N/A

Four production blasts were sampled for sulphur dioxide levels. Sample results are shown in Figures 5, 6, 7, 8, 9 and 10. The summarized gas sampling results are set out in Tables 4 and 5.

Table 4 Gas Sampling Results (K330 Stope).

Date July,1988	Concentration Maximum (ppm)	Concentration Minimum (ppm)	Time to Minimum (Hrs)	Initial Vent. m^3/s	No. of Holes/ Round	Control Methods
18*	910	8	3.5	5.7	P7=50 P9=65	Water atomizer
21	10.6	0	0.5	3.3	P9=25 337-2C=52	Water atomizer and water bags
23**	>50	0	~1	-	P9=57	Water atomizer and Dupont Inert

* 200 metres of ventilation tubing was damaged and burnt. In addition compressed air and water pipes were damaged and two shifts production delays were experienced. Production resumed after restoration of the ventilation, compressed air and water supply systems.

** As measured by long duration and diffusion tubes.

Table 5 Gas Sampling Results.

Date	Location	Concentration (ppm) Max.	Min.	Initial Vent. m^3/s	No. of Holes per Round	Control Methods
1988						
31/05	K330 Stope	232	8	-	N/A	-
20/07	343 Sump	10.3	0/0.5*	64.52**	23-350 Stope 60 holes	-

* Minimum concentration = 0 ppm and time taken from maximum concentration to minimum = 30 minutes.

** Airflow through the stope and the 366 ramp.

6.0 LITERATURE REVIEW AND DETECTORS MANUFACTURERS LIST

6.1 RELATED DETECTORS MANUFACTURERS LIST

Requests for catalogues and other information were sent to 41 instrument companies regarding SO_2 detection systems. The letter of request is shown in Appendix B. Responses received totalled 20, these are shown by a star besides the company's name in the list below. Of the 20 responses received, 1(5 percent) is involved in mining applications and has good potential for use in this project; 11(~55 percent of the total responding) were categorized as "may be applicable".

The complete vendor survey list, is as follows, and is coded with the following designations:

* Reply Received ** Used in Mines *** May be Applicable
**** Not Applicable ***** Request letter Returned
*+ No Reply Received.

1. AFA - Minerva (EMI) Ltr.
   Security House, Grosvenor
   Twickenham TWI 4AB
   England *+

2. Andros, Incorporated
   2332 Fourt Street
   Berkeley, CA 94710
   USA *+

3. Babcock and Wilcox
   Baily Meter Company, USA
   7800 Capwell Drive
   Oakland, CA 94621
   USA *****

* 4. Bacharach Instrument Company
625 Alpha Drive
Pittsburgh, Pa. 15238
USA ****

5. Beckman Instruments, Inc.
Scientific and Process Instruments Division
2500 Harbor Blvd.
Fullerton, CA 92634
USA *+

6. Bendix
Environmental and Process Instruments Division
P.O. Drawer 831
Lewisburg, WV 24901, USA *+

* 7. Brunswick Corporation
Defence Division
3333 Harbor Blvd.
Costa Mesa, CA 92626
USA ****

* 8. Calibrated Instruments Inc.
731 Saw Mill River Road
Ardsley, N.Y. 15020
USA ***

* 9. Casella London Ltd.
Regents House
Brittania Walk
London N17ND
England ****

* 10. DuPont Company
Instrument Products Division
Wilmington, DE 19898
USA ****

11. Dynamation, Incorporated
P.O. BOX 2253
Ann Arbor, MI 48106
USA *****

12. CEA Instruments Inc.
15 Charles Street
Westwood, NJ 07675
USA *****

* 13. CEA Instruments Inc.
16 Chestnut Street
P.O. BOX 303
Emerson, New Jersey 07630
USA ***

14. Energetics Science, Inc.
4461 Bronx Blvd.
New York, New York 10470
USA *****

* 15. ENMET
2308 S. Industrial Highway
Ann Arbor, MI 48104
USA ***

* 16. Environment One Corp
2773C Balltown Road
Schenectady, NY 12309
USA ****

* 17. FEMCO
2000 Betheldrive
P.O. BOX 33
High Point, North Carolina 27261
USA ****

18. Gammaflux, Inc.
1821 Michael Faraday Dr.
Reston, VA 22090
USA *****

19. Gas Analyzer System
Devco Engineering Ltd.
Control Systems Division
36 Pier Lane West
Fairfield, NJ 07006
USA *+

* 20. H. Maihak AG
Seinperstrasse 38
2000 Hamburg, GO
Federal Republic of Germany ****

* 21. Horiba Instruments
1021 Duryea Avenue
Irvine, CA 92714
USA ***

22. International Sensor Technology
3201 South Halladay Street
Santa Ana, CA 92705
USA *****

* 23. Interscan Corporation
21700 Nordhoff Street
Chatsworth, California 91311
USA ***

* 24. Institut De Recherche d'Hydro - Quebec
IREQ
1800 Montee Ste - Julie
Varennes, Quebec, Canada
JOL 2P0 ***

* 25. Infrared (I.R.) Industries Inc.
P.O. BOX 989
Santa Barbara, CA 93012
USA ***

26. Kidde Automated Systems, Inc.
725 G County Line Road
Deerfield, IL 60015
USA *****

27. Leeds and Northrup Co.
1700 S. El Camino Real
San Mateo, CA 94070
USA *****

* 28. Line Power Manufacturing Corp.
Division of Electro - Mechanical Corporation
329 Williams Street, Bristol,
Virginia 24203 - 8200
USA ***

29. Meloy Labs Inc.
Instuments & Systems Division
6715 Electronics Division
Springfield, VA 22151
USA *+

30. MSA
Instrument Division
400 Penn Central Blvd.
Pittsburgh, PA 15235
USA *+

31. National Mine Service Co.
East of City
P.O. Drawer 698
Price, Utah 84501
USA *+

* 32. Omega Eng. Inc.
One Omega Drive
P.O. BOX 4047
Stanford, CT 06907
USA ****

* 33. Ohio Brass Co.
380 North Main Street
Mansfield, OH
USA ****

34. Phillips Electronic Instruments
85 McKee Drive
Mahwah, NJ 07430
USA *****

* 35. Process Analysers Inc.
3 Headly Place
Fallsington, Pa. 19054
USA ***

36. Rochester Instrument Systems
255 North Union Street
Rochester, NY 14605
USA *+

* 37. Rosemount Instruments Ltd.
4224 Manor Street
Burnaby, B.C., Canada
V5G 1B2 ***

38. Scott Automation - Davis Instrument
P.O. BOX 751
RT 29 North
Charlotteville, VA 22902
USA *****

39. Wilkes Scientific Co.
Norwals, CT
USA *+

* 40. Yellow Springs Instrument Company, Inc.
P.O. BOX 279
Yellow Springs, Ohio 45387
USA ***

* 41. Anglo American Electronics Laboratory
Booysens Reserve Road,
Theta Township, Johannesburg,
RSA.

6.2 COMMERCIALLY AVAILABLE INSTRUMENTATION

This section reviews some of the commercially available instruments that may be suitable for monitoring SO_2 in underground mines. Considering all combinations of mobility, power requirement, and output characteristics, up to 16 instrument types are theoretically possible for monitoring SO_2. Individual summaries are given in terms of the manufacturers'name and the sensor characteristics. Key performance characteristics are summarized in a common format. This information was developed from manufacturers'literature and conversations with their technical personnel.
Additional information was collected by reviewing research reports and journal articles. Pricing and manufacturers' information contained in the instrument summaries is based on 1988 prices, and is subject to change.

USE OF VENDOR NAMES

Reference to specific equipment or trade names in this report does not imply endorsement of the products by the investigators.

Table 6 Sulphur Dioxide Detectors

Vendor	Model	Type	Manufacturer's Recommended Range (PPM)	Maintenance	Input Power	Signal Output	Appr. Cost
Anglo American Electronics Laboratory *	Spanair	NDIR	25 to 2500	Replace filter, clean, recalibration	120 V AC	0 - 1 V	$2000/Head
Bendix (Maihak)	UNOR 1 **	IR	0 to 500	Periodic Calibration	120/220 VAC	0.1 - 1 mA	$4000
Calibrated Instruments	Ultragas-U3EK-SO2	Conductivity	0 to 75	2 months	220 VAC	0 - 20 mA	$30500
CEA Instruments, Inc	SO-7	Electrochemical	0 to 15	Unknown	110 V/ Battery	LCD	$1995
Ermet Corporation	TG-500	Membrane electrolysis	0 to 15	Unknown	110/220 VAC	0 - 10 DC	
Horiba	APSA - 300E	UV Fluorescent	0 to 5	Unknown	115 VAC	0 - 1 VDC	$13750

* Over 120 in deep gold mines, South Africa.

** Common in European Coal Mines

Vendor	Model	Type	Manufacturers Recommended Range (PPM)	Maintenance	Input Power	Signal Output	Approx. Cost ($)
Inter-Scan	1248	Electro-chemical	0 to 10 0 to 25 0 to 50	N/A	AC/DC	0-100 mV	4000
Inter-Scan	1240	Electro-chemical	0 to 5	N/A	AC/DC	0-100 mV	4000
Inter-Scan	4245	Electro-chemical	0 to 5	N/A	AC/DC	0-100 mV	3500
	4247	"	0 to 10	N/A	"	"	3500
4240	4249	"	0 to 50	N/A	"	"	"
Series	4240Sp	"	Special Ranges	N/A	"	"	"
Inter-Scan	LD-24	Electro-chemical	0 to 5	N/A	"	"	3500
			0 to 10	"	"	"	"
LD-24			0 to 50	"	"	"	"
Series			0-10/0-50	"	"	"	"
Energ-tics Sc. Inc.	Ecolyzer 5005-PGF -10	Electro-chemical	0 to 10	N/A	15-28 VDC	4-20 mA 0-1 V	1890
Sieger	Sieger 911	Electro-chemical	0-100	N/A	20-35 VDC	4-20 mA	1100

Vendor	Model	Type	Manufacturers Recommended Range (PPM)	Maintenance	Input Power	Signal Output	Appr. Cost
Nova Tection	Toxtector III	Electrochemical	0-1000	N/A	AC/DC	0-1 VDC	1900
Neotronics	SO103	Electrochemical	0-3999	N/A	AC/DC	0-1 VDC	N/A
Infrared Industries Inc.	IR-7200	NDIR	0-20000	Internal Span Check	115 VAC	N/A	N/A
City Technology Ltd.	3SF & 3ST	Electrochemical	0-2000	N/A	N/A	0-1 VDC	N/A
			0-25	N/A	N/A	"	N/A

N/A = Not available

6.3 EXAMPLES FROM LITERATURE REVIEW

Several techniques are available for measuring sulphur dioxide gas concentration. Of these, four sensing techniques will be reviewed: i) Infrared, ii) Fluorescence, iii) Semi-conductors, and iv) electrochemical. The principal interferents for each technique are also given in Table 7.

Search of literature was carried out utilising staff and resources available in the University of British Columbia library, Science Division.
The following resources were used:

i) NTIS, National Technical Information Service, and
ii) Engineering Index; Conferences and Meetings.

6.3.1 UV-Fluorescence

1. Westerberg, B., "Continuous Monitoring System for SO_2 and NO_x Measurements in the Danish Air-Quality Measuring Project"; Report MST - LUFT-A-76, JUL. 1983; Miljoestyrelsen, Roskilde (Denmark).

Abstract

In a Danish air quality monitoring network, sulphur dioxide and nitrogen oxides are continuosly monitored at a main station, situated in an urban centre. The present report describes the instrumentation, monitors and data acquisition system, employed in the 6 cities, outside the Greater Copenhagen area, covered by this network. Detection of sulphur dioxide utilizes the UV-Fluorescence method (monitor labs 8850) and of nitrogen with ozone (monitor labs 8840). Ambient air is drawn in 2-2.5 m teflon tubes to the monitor by their associated pumps (ca. 0.5 l/min). The temperature in the station is controlled to within ± 2 °C. As a functional test of monitor calibration, zero points are determined. For the sulphur dioxide monitor, results of testing the hydrocarbon scrubber at the routine calibration by monitoring relatively high concentrations of -Xlene are given. For the NO_x monitor, possible interference by thermal dissociation of N-compounds are given special attention. The role of water vapour as a possible interferent in both methods are investigated. (NTIS)

2. Maffiolo, G. and Leriquier, Y., "Laboratory and in-situ Comparative Study of Four Analyzers of Sulphur dioxide in Atmosphere"; Jan. 1982; Electricite De France, Chatou.

Abstract

The tests performed on three UV-Fluorescence analyzers and one flame photometry analyzer have enabled the in-laboratory study to be made (a) on the response time of the appliances, their calibration curve, their specificity and drift and (b) their reliability and response to be compared in-situ. Given the results as a whole, the principle of UV-Fluorescence appears to present the most interesting characteristics for carrying out in-situ determinations. Among the three appliances making use of this principle, the "environment SA AF20" apparatus appears to give the best results, essentially from the stability point of view. (NTIS).

3. Okabe, H, "Fluorescence Quenching of Sulphur Dioxide by Source Emission Gases; Analytical Chemistry, V48 N11, Sept. 1976, P1487 - 1489. (NTIS).

4. Schwarz, F.P., Okabe, H, and Wittacker, J.K., "Fluorescence Detection of Sulphur Dioxide in Air at the Parts per Billion Level"; Analytical Chemistry, V46 N8 P1024 -1028, July, 1974. (NTIS).

5. Okabe, H, Splitstone, P.L., and Ball, J.J., "Ambient and Source SO_2 Detector Based on a Fluorescence Method"; Journal of the Air Pollution Control Association, V23 N6 June, 1973, P514 - 516. (NTIS).

Abstract

The principle of this detector is based on the measurement of the intensity of the ultraviolet fluorescence of SO_2 produced by absorption of the Zn 2138 Angstrong or Cd 2288 Angstrom line. The fluorescence intensity was found to be linear from 0.1 to 500 ppm of SO_2 in air with the Zn lamp and from 0.1 to 1600 ppm with the Cd lamp. The detection limit at present is about 20 ppb. There is no detectable interference from O_3, H_2S, NO_2, CO_2, CO, or H_2, although the presence of a large concentration of CS_2(500 times as much as SO_2) NO(500 times) or C_2H_4 (4000 times) interferes with the measurements. The presence of 2% H_2O reduces the signal by 25%, while up to 1% CH_4 has almost no effect.

6. Wolfe, L.C., and Giever, P., "Design, Fabrication and Evaluation of a Fluorescence Sulphur Dioxide Monitor"; Research Appliance Company Gibsonia, Pennsylvania; Presented at the 68th Annual Meeting of the Air Pollution Association, Boston, Massachusetts,; June 15-20, 1975.

Abstract

The paper describes the design, fabrication and evaluation of a continuous fluorescent sulphur dioxide monitor, in which the sample is drawn into a cell and irradiated by a monochromatic ultra-violet source. Sulphur dioxide molecules present in the sample stream show a specific response to the short UV radiation (2138 Angstrong) and fluorescence at a longer wave length (2400 to 4200 Angstrong). The level of this fluorescence is directly related to the partial pressure of sulphur dioxide in the sample stream.

Field testing of the instrument described has shown it to be rugged, dependable and accurate. The fluorescent signal is continuously corrected for any variation in the intensity of the irradiating source. Further corrections are made for detector dark current and stray light. The end-on photomultiplier detector operates in the photon counting mode, resulting in a wider linear detecting range and better base line stability. The photon pulses are processed and displayed by a random logic digital system. The results of laboratory and field testing are given and compared to the more classical wet chemistry methods.

7. Syty, A., "Determination of Sulphur dioxide by Ultraviolet Absorption Spectrometry"; Anal. Chem., 45, 1744-1747, August 1973.

8. Okabe, H., "Fluorescence and Predissociation of Sulphur dioxide"; J. Amer. Chem. Soc., 93, 7095-7096, December 1971.

9. Warneck, P., Marmo, F.F. and Sullivan, J.O., "Ultraviolet Absorption of SO_2: dissociation Energies of SO_2 and SO"; J. Chem. Physics, 40, 1132-1136, February 1964.

6.3.2 Electrochemical

1. Boehm, H., "Electrochemical Apparatus for Analyzing Carbon Monoxide, Hydrogen Sulphide, Hydrogen and Sulphur dioxide"; Allgemeine Elektricitaets-Gesellschaft, AEG Telefunken, Frankfurt Am Main(Germany, F.R.); Forschungsinstitut, Nov. 1978; 20P. (NTIS).

2. Boehm, H., "Electrochemical Apparatus for Analyzing Carbon Monoxide, Hydrogen Sulphide, Hydrogen and Sulphur dioxide"; Aeg-Telefunken, Frankfurt Am Main (Germany, F.R.); Nov. 1978; 18P; Final Report. (NTIS).

3. Shults, W.D. and Kuempel, J.R., "Electrochemical Air Pollution Monitoring Device and Method of Use Therof"; Atomic Energy Commision, Washington, D.C., Patented 30 Jan 73; 10P; Copy of Patent Available Commisioner of Patents, Washington, D.C. 20231 Do.50; Patent. (NTIS).

4. Jefferson, R.H. and Khalafalla, S.E., "Gas Diffusion Membrane Electrode to Determine SO_2 in the Presence of SO_3"; Bureau of Mines, Twin Cities, Minn. Twin Cities Metallurgy Research Center; December, 176; 19P, Report of Investigations, RI-8200.

Abstract

An electrochemical method to selectively determine sulphur dioxide in the presence of sulphur trioxide was investigated.

A hydrophobic gas-permeable membrane separates the gas sample solution, from an internal filling solution containing a fixed quantity of chloride ion and a sufficiently large excess of sodium bisulphite so that its concentration may be considered constant. Sulphur dioxide diffuses through the membrane to dissolve in the internal filling solution and liberates an equivalent quantity of hydrogen ions. The electromotive force between a precision-ground, flat-ended P^H electrode, which acts as the sensing element, and a chloride sensing electrode, gives a direct measure of SO_2 in the gas sample solution. Calibration curves in water, tetrachloromercurate (TCM), and citrate buffer absorption solutions were closely parallel with slopes in their linear segments, ranging from 57 to 52 mv/decade of SO_2 concentration.

The slopes compare reasonably well with the theoretically expected slope of 58 millivolts at 21°C. The water standard curve was linear with respect to the logarithm of SO_2 concentration from 1 to 1,000 ppm SO_2; the TCM standard curve was linear from 10 to 2000 ppm SO_2; and the citrate standard curve was linear from 30 to 5000 ppm SO_2. The high efficiency and nontoxicity of citrate favor it as a substitute for the conventionally used TCM in the absorption solution.

5. Driscoll, J.N., "Validation of Improved Chemical Methods for Sulphur Oxide Measurements From Stationary Sources"; EPA Report R2-72-105, December 1972, 215P.

6. Dillon, J.A., "Monitoring Sulphur dioxide"; Instr. and Control Systems, V. 45, No. 4, 1972, P23.

7. Kenneth, L.W., "Measuring Gaseous Pollutants from Diesel Exhaust in Underground Mines"; In Diesels in Underground Mines; Proceedings: Bureau of Mines Technology Transfer Seminar, Louisville, KY, April 21, 1987, and Denver, CO, April 23, 1987; Bureau of Mines IC 9141.

6.3.3 Infrared

1. Morris, R.N., "Use of Semi-conductor Laser in Infrared Spectroscopy"; Ames Lab., Iowa; Department of Energy; Dec. 1977; 157P; Thesis. (NTIS).

2. Bohlander, R.A., et al., "A Report of a Measurement of Absorption of Sulphur dioxide in the Range 460 CM(-1) to 560 CM(-1)"; Colorado Univ., Boulder Dept. of Physics and Astrophysics; National Oceanic and Atmospheric Administration, Boulder, Colorado Environmental Research Lab.; Dec 1977; 18P; Final Report. (NTIS).

3. Burch, E.E., and Gryvnak, D.A., "Infrared Gas Filter Correlation Instrument for In-situ Measurement of Gaseous Pollutants"; Philco-Ford Corp., Newport Beach, Calif. Aeronutronic Div.; National Environmental Research Center, Research Triangle Park, N.C. Chemistry and Physics Lab.; Final Report, Dec. 1974; 64P. (NTIS).

4. Burch, D.E., et al., "Absorption and Emission by SO_2 Between 1050 and 1400/CM (9.5-7.1 Micrometres)"; Philco-Ford Corp., Newport Beach, California Aeronutronic Div.; Final Technical Report, Jul 1971; 59P.

5. Lepper, J.M. JR, For Study of Infrared Techniques for Monitoring Stack Gases", Dalmo Victor Co., Belmont, California; Final Rept. 12 Oct 1965; 60P. (NTIS).

6. Eggers, JR., and Schmid, E.D., "Infrared Intensities of Sulphur dioxide: A Redetermination"; Journal of Physical Chemistry (U.S.) V64 P279-80; 1960.

7. Bartle, E.R., and Meckstroth, E.A., "Infrared Sensor for the Remote Monitoring of SO_2"; JRB Associates, Inc., LA Jolla, Calif.; National Environmental Research Center, Research Triangle Park, N.C. Chemistry and Physics Lab; May 1975, 55P; Final Report; Rept. EPA/650/2-75-041, Project EPA-ROAP-26AAP, Contract EPA-68-02-1208. (NTIS).

8. Annon., "Optical Measurements of SO_2 and NO_2 Air Pollution Using Barringer Correlation Spectroscopes"; Barringer Research Ltd., Rexdale (Ontario); December 1969; 203P; Final Report; Report TR69-113, Contract PH-22-68-44. (NTIS).

9. Kenneth, L.W., et al., "Measuring Gaseous Pollutants from Diesel Exhaust in Underground Mines"; In Diesel in Underground Mines; Proceedings: Bureau of Mines Technology Transfer Seminar, Louisville, KY, April 21, 1987, and Denver, CO, April 23, 1987; Bureau of Mines IC 9141.

Abstract

Several techniques are available today for measuring gaseous pollutants from diesel exhaust such as carbon monoxide, carbon dioxide, nitric oxide, nitrogen dioxide, and sulphur dioxide. Four gas-sensing techniques are discussed: electrochemical, infrared, detector tubes, and passive samplers. For each technique, the general operating principles are described, and a discussion of measurement range, response time, accuracy, interferences, power requirements, life, and cost is included. Selecting the most appropriate technique is challenging. Each of the four techniques have benefits and shortcomings that must be evaluated in the light of the sampling objective. At present, no "recommended" sampling or measurement protocol is available. A complete discussion of the problem of measuring gases present in diesel exhaust would require several large volumes. This paper is intended as an introduction to the problem.

6.3.4 Semi-conductor

1. Plihal, M., et al., " Gas-Sensitive Semi-conductor Field-Effect Sensors"; Siemens A.G., Munich (Germany, F.R.); Forschungslaboratorium; Bundesministerium Fuer Forschung Und Technologie, Bonn-Bad Godesberg(Germany, F.R.); July 1982; 78P, Final Rept; Transactions of Unidentified Mono., N. P., Nov. 1980.

Abstract

Modified silicon field-effect transistor (FET) and misdiodes as well as semi-conducting metal oxides were examined for their suitability for the detection of CO, CO_2, SO_2, NO, N_2O, and NH_3 gases. The channel conductivity of silicon semi-conductor structures was field controlled by the effect of gases and vapours on a sensitive layer of organic material, zeolite or palladium. The conductivity of the material changed for semi-conductor oxides. There was no success with gas sensors having organic layers or zeolite. The selective detection of H_2 was achieved using mis-diodes with palladium. Oxidisable gases in air could be detected with the semi-conducting metal oxide gas sensors. An increase in sensitivity was achieved compared with established systems and the first indication of selective gas detection was observed.

2. Andre Belanger (January 26, 1988), Personal Communication to Dr. A.E. Hall; Service Chimie des Materiaux, IREQ, C.P. 1000, Varennes, Quebec, J0L 2C0.

6.3.5 General References

1. Thomson, D.W., De Pena, R.G., and Pena, J.A., "Environmental Measurements of Power Plant Cooling Tower and Stack Plumes"; Pensylvania State University, Dept. of Meteorology, University Park, 1981, 180P; Report DOE/EV/02463-6, Contract AS02-76EV02463. (NTIS).

2. Herget, W.F. and Brasher, J.D., "Remote Fourier Transform Infrared Air Polution Studies"; Optical Engineering, V19 N4 P508-514, July/August 1980, Report EPA-600/J-80-244. (NTIS).

3. Proctor, E.K. and Byer, R.L., "Remote Measurement of Air Pollutants"; Stanford Research Institute, Irvine, California; National Science Foundation, Washington, D.C., Engineering and Applied Science; 31 January, 1975, Report No. 2 (Annual), 42P. (NTIS).

4. Jahnke, J.A. and Aldina, G.J., "Continuous Air Pollution Source Monitoring Systems"; June 1979, Report EPA/625/6-79/005, Contract EPA-68-03-2561. (NTIS).

5. McClenny, W.A., et al., "Evaluation of Techniques for Measuring Biogenic Airborne Sulphur Compounds, Cedar Island Field Study"; January 1979, 138P; Prepared in Cooperation with University of South Florida, Tampa, Dept. of Chemistry; PC A07/MF A01; Report EPA/600/2-79/004. (NTIS).

6. Heidam, N.Z. and Jensen, F.P., "Nordic Intercalibration of of Airborne Equipment for Measurement of Sulphate and Sulphur dioxide"; Riscoe National Lab., Roskilde (Dermark), April 1977, 42P. (NTIS).

7. Becker, M., "Sensor for Automatic Continuous Emission Control of Gases"; Standard Elektrik Lorenz A.G., Stuttgart (F.R. Germany), Forschungszentrum; February 1976, 24P. (NTIS).

8. Meserole, F.B., et al., "Sulphur dioxide Interferences in the Measurement of Ambient Particulate Sulphates"; Radian Corp., Austin, Texas; Electric Power Research Institute, Polo Alto, California; February 1976, Final Report; Report EPRI-262-VOL-2; Project EPRI-262. (NTIS).

9. Annon., "Report on Sulphur Dioxide Study"; Iowa Dept. of Environmental Quality, Des Moines, Air Quality Management Division; October 1975; 203P. (NTIS).

10. Okabe, H., "Sulphur dioxide Pollution Monitor"; Department of Commerce, Washington, D.C., Patented 5 March 1974, Report Patent Application-309868, Patent-3795812.

11. Annon., "Sulphur dioxide Pollution Monitor"; National Bureau of Standards, Washington, D.C.; Filed 27 November 1972; 8P, Report Patent - Application - 309868.

11. Gannoe, R.E., Riley, G.R., and Frink, D.W., "Gas Monitoring Equipment Investigation"; Battelle Memorial Institute Columbus Ohio Columbus Labs; 1971, 122P; Interim Report; Contract N00014-69-C-0352. (NTIS).

12. Annon., Studies of the Measurement of Sulphur dioxide in Stack Gases. Three Concurrent Studies; Industrial Nucleonics Corp., Columbus, Ohio; 177 370; 29 January 1968; 315P; Prepared in Cooperation with International Chemical and Nuclear Corp., Pittsburgh, Pa.; Nuclear Science Division, and Texas Nuclear Corp., Austin; PC., Contract AT(30-1)-3882; AT(30-1)-3881. (NTIS).

13. Wallace, D.A., and Perkins, W., "Alarm-Level Monitor for SO_2 Emissions from Stationary Sources"; February 1977, 34P; Report EPA/600/2-77/021; Contract EPA-68-02-2233. (NTIS).

14. Stevens,R.K. and O'Keeffe, A.E., "Modern Aspects of Air Pollution Monitoring"; Anal. Chem., 42, 143A-149A, Feb. 1970.

15. Rhodes, C.E., et al., "Performance Characteristics of Instrumental Methods for Monitoring Sulphur dioxide"; Part I, Journal of Air Pollution Control Association, 19, 575-584, August 1969.

16. Palmer, H.F., et al., "Performance Characteristics of Instrumental Methods for Monitoring Sulphur dioxide"; Journal of Air Pollution Control Association, 19, 778-786, October, 1969.

17. Shikiya, J.M., and MacPhee, D.R., "Multi-instrument Performance Evaluation of Conductivity-type Sulphur dioxide Analyzers"; Journal of Air Pollution Control Association, 19, 943-945, December 1969.

Table 7 Interferents or Cross-sensitivity

Sensing Technique	Interferents
UV- Flurescence	Water Vapour, H_2S, C_2H_4, CS_2, NO, O_3
Electrochemical	Cl_2>500, CO>500, COS>500, H_2>500, H_2S*, NH_3=45, NO>500, N_2O>10^4 NO_2 = -10, SO_3 >10^4 **
Infrared	Methane (CH_4), Water vapour

* Scrubber required since H_2S is a critical interfering agent.

** The approximate concentration (ppm) of interfering gas needed to cause a 1 ppm deflection in the SO_2 sensor.

Table 8 3ST and 3SF Cross-sensitivity to Other Gases at 20°C

Gas	Concentration of Gas Used	Approximate Equivalent SO_2 Signal	
		Type 3ST	Type 3SF
Hydrogen	100 ppm	1 ppm	3 ppm
CO_2	25%	0 ppm	0 ppm
CO	200 ppm	0 ppm	< 5 ppm
Methane	5%	0 ppm	0 ppm
Ethylene	100 ppm	0 ppm	0 ppm
H_2S	100 ppm	~ 200 ppm	~ 200 ppm *
Chlorine	10 ppm	< 0.6 ppm	< 1 ppm
NO	50 ppm	0 ppm	0 ppm
NO_2	10 ppm	~ 10 ppm	~ 10 ppm
Alcohols	100 ppm	< 1 ppm	< 1 ppm
Ammonia	50 ppm	0	0 ppm

* In-board filter for 3ST sensor available upon request.

7.0 DISCUSSION OF RESULTS

7.1 DEVIATION IN SPAN AND ZERO

The span, zero drift and stability for all the sensors are quite impressive. The 3ST sensor was found to have 0.9% of full-scale drift for span and 0.5% of full-scale drift for zero readings; while the 3SF sensor showed 1.1% of full-scale drift for span readings.

The data in this test program have not been corrected for any of the interferents. This interference problem should be considered when the SO_2 data is interpreted. Like most electrochemical sensors, these also respond to certain other gases. Manufacturers' literature shows positive hydrogen, CO, H_2S, chlorine and alcohol interferences while negative NO_2 interferences are experienced.

7.2 GAS SAMPLING

Tables 4 and 5 show gas sampling results. One major sulphide dust explosion occurred on July 18, 1988. The explosion released a sulphur dioxide concentration of 910 ppm with a decaying time of 3.5 hours. The decay time was quite long because the explosion disturbed the stope ventilation system. Two panels were blasted simultaneously and water fogging was the only control method employed for sulphide dust ignition prevention. Four more ignitions were recorded during the experimental period.

It is thought that, these concentrations are lower than the concentration at source. This may be due to the following reasons:-

1. Scrubbing Effect of Water
   A fraction of sulphur dioxide gas is removed from the atmosphere by water droplets before it reaches the sensors. SO_2 is a water soluble gas. In order to quantify this effect, blasting without water atomizers is necessary.

2. Reaction with Blasting Pollutants
   Sulphur dioxide and ammonia vapour in the presence of excess water vapour or droplets react according to the following equations:-

$$NH_3 + H_2O + SO_2 \longrightarrow NH_4.HSO_3$$
$$2NH_3 + H_2O + SO_2 \longrightarrow (NH_4)_2SO_3$$

3. Cross-sensitivity to Other Gases
   Interference from other gases may have affected the readings. The effect of other gases is given in Table 8. Most of these gases in Table 8 are also by-products of explosive decomposition produced in trace amounts.

7.3 LITERATURE REVIEW

A large number of electrochemical(sample-draw or diffusion) sensors for detecting SO_2 are available on the market. NO and NO_2, common pollutants in diesel exhaust and sulphide dust explosion and interferents for electrochemical SO_2 cells as well as H_2S, are easily removed by chemical filters. Interscan Corporation markets a scrubber model number 170 for this purpose. City Technology Limited offers a filter for the 3ST sensor to remove cross-sensitivity to hydrogen sulphide.

Suitable infrared instruments for monitoring sulphur dioxide are also available. Anglo American Spanair monitor is on shelf and has been designed for underground mine use, but is bulky and difficult to import and service. The infrared sensing technique for determining SO_2 concentration is limited by the physical properties of sulphur dioxide gas. Due to its low infrared absorbance capacity, detection at lower concentrations requires a long path length. Infrared instruments with small-length sample cells would not be sufficiently sensitive to measure SO_2 over the concentration ranges required for health monitoring.

Available instrumentation must survive the rugged underground mine conditions. The sensors must be constructed to withstand high dust levels, relative humidity to 100 percent and corrosive atmospheres. A low requirement for maintenance and calibration is best suited to underground mines. In view of these requirements the following additional monitors are considered to be suitable for underground installation:-

- Spanair Analyzer (Anglo American Corporation Electronics Laboratory - South Africa);
- LD-24 Series (Interscan Corporation); and
- Unorl (Bendix - Maihak).

Of these Interscan systems are selected due to their design reliability and these systems are presently installed in North American power plants. Spanair is not available in North America, the required filters are very expensive and it is no longer manufactured to any extent. Spanair systems are presently installed in deep South African gold mines.

APPENDIX A

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3ST AND 3SF SENSOR SPECIFICATIONS

SULPHUR DIOXIDE SENSORS

CTL sulphur dioxide sensors are electrochemical sensors of the micro fuel cell type, designed to be maintenance free and stable over long periods of time.

The sensors use the capillary diffusion barrier technology which has proved so successful in the CTL C/S oxygen sensor. This results in a low temperature coefficient and a direct response to concentration (volume %), relatively unaffected by pressure. The use of electrodes based on fuel cell technology gives a high reserve of activity which makes for long term stability.

Sulphur dioxide diffusing to the sensing electrode (anode) reacts according to the equation:

$$SO_2 + 2H_2O = H_2SO_4 + 2H^+ + 2e$$

At the counter electrode (cathode) the reaction is:

$$^1/_2\ O_2 + 2H^+ + 2e = H_2O$$

the oxygen requirement being automatically supplied from the ambient air by controlled diffusion.

Sulphur dioxide sensors are manufactured in 2 ranges. Type 3ST for trace readings of up to 100ppm & type 3SF for readings of up to 2000ppm for flue gas analysis. Both sensors are offered in the same hardware (Figure 5). The significant difference is the output signal which is increased by ≈ 3 times in value for the trace sensor.

CTL sulphur dioxide sensors are of the three-electrode type which are only available under special conditions of sale. These sensors are designed for a particular mode of operation whereby the change in potential of the sensing electrode on exposure to sulphur dioxide constitutes the signal which is proportional to concentration.

A circuit for control and operation of the type 3ST sensor is shown in Figure 3 and for the type 3SF sensor in Figure 4.

CALIBRATION

For maximum accuracy, the sensor should be calibrated using a gas mixture in the range where most measurements are to be made, or where the greatest accuracy is required. Otherwise a mixture towards the top end of the sensors normal measuring range should be chosen. On no account should mixtures in the over range capacity of the sensor be used for calibration purposes.

The calibration gas mixtures may be used with nitrogen or air as the balance gas, and normally a 2 minute exposure would be deemed satisfactory.

TYPE 3ST TRACE
SULPHUR DIOXIDE SENSOR CHARACTERISTICS

1. Primary sensitivity	Direct % SO_2
2. Range	0-100ppm output 2.5ppm = 1volt
3. Output signal (Note 1 Page4)	0.37μA/ppm ± 0.07μA/ppm
4. Operating life in air at S.T.P.	Expected 1-2 years
5. Preconditioning requirements	1 hour on load
6. Storage life in CTL container under clean dry conditions at 0-20°C	> 6 months
7. Operating temperature range continuous	-15°C to +40°C
Operating temperature range intermittent	-20°C to +55°C
8. Effect of operating temperature on accuracy (Note 2 Page 4)	Figure 1
9. Operating pressure range	Ambient ± 10%
10. Effect of operating pressure on accuracy (Note 3 Page 4)	≈ 0.05% signal per mm Hg
11. Operating relative humidity range For continuous operation see Technical Information Sheet No.11	Intermittent 0-99% RH non condensing
12. Effect of operating relative humidity on accuracy	Sensor follows changes in SO_2 concentration due to changes in RH
13. Position sensitivity	None
14. Full scale output drift S.T.P. continuous duty in air	< 2% FSD/month
15. Baseline (pure air, 20°C)	< 0.35ppm equivalent SO_2
16. Response time to 90% of final reading (step change) at 20°C with 10 ohm load resistor	< 25 seconds
17. Size - Diameter x Height	42mm x 19mm
18. Weight	≈ 22g
19. Cross sensitivity to other gases	Note 4 Page 4
20. Linearity	Linear to Volume % SO_2 0-100ppm

TYPE 3SF FLUE GAS

SULPHUR DIOXIDE SENSOR CHARACTERISTICS

1. Primary sensitivity	Direct % SO_2
2. Range	0-2000ppm = 1volt
3. Output signal (Note 1 Page 4)	0.1 μA/ppm ± 0.02 μA/ppm
4. Operating life in air at S.T.P.	Expected 1-2 years
5. Preconditioning requirements	1 hour on load
6. Storage life in CTL container under clean dry conditions at 0-20°C	> 6 months
7. Operating temperature range continuous	-15°C to +40°C
Operating temperature range intermittent	-20°C to +55°C
8. Effect of operating temperature on accuracy (Note 2 Page 4)	Figure 2
9. Operating pressure range	Ambient ± 10%
10. Effect of operating pressure on accuracy (Note 3 Page 4)	≈ 0.05% signal per mm Hg
11. Operating relative humidity range for continuous operation see Technical Information Sheet No.11	Intermittent 0-99% RH non condensing
12. Effect of operating relative humidity on accuracy	Sensor follows changes in SO_2 concentration due to changes in RH
13. Position sensitivity	None
14. Full scale output drift S.T.P. continuous duty in air	< 2% FSD/month
15. Baseline (pure air, 20°C)	± 2ppm equivalent SO_2
16. Response time to 90% of final reading (step change) at 20°C with 33 ohm load resistor	< 30 seconds
17. Size - Diameter x Height	42mm x 19mm
18. Weight	≈ 22g
19. Cross sensitivity to other gases	Note 4 Page 4
20. Linearity	Linear to volume % SO_2 0-2000ppm

NOTE 1: Output Signal

The output from the type 3ST sensor when supplied will be between 0.3μA/ppm and 0.44μA/ppm at 20°C and the 3SF sensor will be 0.08μA/ppm & 0.12μA/ppm.

When designing an instrument it is important to allow sufficient range in the calibration resistor to cover changes in sensitivity from sensor to sensor, together with changes caused by temperature variations and long term drift.

NOTE 2: Temperature Effects

(a) Span

Figure 1 shows the typical variation in sensor output with temperature for a sensor calibrated at 20°C to a reading of 100% from a suitable test gas.

(b) Baseline

The baseline signal follows an exponential law with temperature change. The baseline approximately doubles for every 10°C increase in temperature.

NOTE 3: Pressure effects

The sensors will give a transient response to a step pressure change. To avoid this effect in pumped systems the sensor should be positioned at the atmospheric end of the train with a minimum of back pressure.

Pumps such as diaphragm pumps which generate pressure pulsations in a sampled gas can affect the signal. Pulsations should be damped out by suitable plumbing. A separate CTL technical leaflet provides guidance on this matter, Technical Information Sheet No. 6.

NOTE 4: Cross sensitivity to other gases at 20°C

Gas	Concentration of Gas Used	Approximate Equivalent SO_2 Signal	
		Type 3ST	Type 3SF
Hydrogen	100ppm	1ppm	3ppm
Carbon Monoxide	200ppm	0ppm	< 5ppm
Carbon Dioxide	25%	0	0
Methane	5%	0	0
Ethylene	100ppm	0	0
Hydrogen Sulphide	100ppm	≈200ppm*	≈200ppm
Chlorine	10ppm	<0.6ppm	< 1ppm
NO	50ppm	0	0
NO_2	10ppm	-10ppm	-10ppm
Alcohols	100ppm	< 1ppm	< 1ppm
Ammonia	50ppm	0	0

* The 3ST sensor can be built with an in-board filter to remove cross-sensitivity to Hydrogen Sulphide. The in-board filter also produces a lower baseline with less temperature drift. The appearance of the sensor is unaltered but the response time may be up to 5% longer. Ask for 3ST/F sensors. See Technical Information Sheet no. 15 for details.

Operation

It is necessary to maintain a supply of oxygen at the non-sensing back side of the sensor for correct operation of the electrodes. Access paths are provided in the back cover slip for the oxygen supply and the sensor should not be completely potted with resin nor totally immersed in an anaerobic gas mixture. When a calibration gas is exposed to the sensing face of the sensor, an inert gas carrier may be used. The calibration gas need not contain oxygen - this is supplied from ambient air through the back access paths.

Start Up

To maintain the sensor in a "ready to work" condition a shorting link is connected across the sensing and reference electrodes when the sensors are despatched from City Technology Limited. This link must remain in place during storage and should only be removed when the sensor is inserted into an instrument. Similarly when an instrument is switched off the shorting link must be reconnected. This can be done by using the ganged switch as shown in our circuit, or by using a 1KΩ resistor permanently connected to ground in place of the switch. An alternative is to use an FET to short the reference to sensing, which is configured so that when the circuit is powered the FET is held in a high impedance mode via an appropriate gate voltage.

Handling

The sensor should not be subjected to any appreciable pressure when handling or clamping.

In particular the underside cover-slip should not be pressed.

The capillary hole should not be poked or prodded.

Do not rotate or move the terminal tags. This may result in breaking the internal electrical connection and/or induce leaks.

The sensor securing bolts are set to give optimum sealing and should not be tampered with.

Glueing the sensor must be avoided as this can lead to crazing of the plastic and damage to the electrodes from high concentrations of solvent vapour.

The sensors contain a small volume of strong mineral acid. In the unlikely event of a leak, the contaminated parts should be rapidly and throughly rinsed in water.

Sampling Systems (see also under pressure)

The sensor should be suitably protected by appropriate filtration to remove highly corrosive constituents and particulate matter, and condensing conditions at the sensor must be avoided.

Electrode Identification

The label on the back of the sensor is marked as follows:-

Sensing electrode	-	S
Reference electrode	-	R
Counter electrode	-	C

NOTES ON 3 ELECTRODE CIRCUITS

1) The output as shown will be negative with respect to common when an oxidising gas is detected.

2) The filter circuit shown can normally be omitted which will allow quicker circuit stabilisation when the circuit is first switched on. Where an output is displayed on a chart recorder the filter gives a worthwhile increase in the clarity of the trace.

3) To check for correct operation of the circuit with sensor connected, measure between the reference terminal and common which should be zero volts.

4) The voltage developed across the load resistor should be restricted to less than 10mV under all conditions otherwise sensor performance will suffer. Since the sensor signal current flows through the load resistor this means it may be necessary to have a switchable load resistor when monitoring very high gas concentrations. For example a sensor with an output of 0.12μA/ppm with a load resistor of 33Ω will give a voltage drop of 7.92mV in a gas concentration of 2000ppm. If monitoring above this concentration we would recommend reducing the value of this load resistor.

5) The function of the counter electrode is to complete the electrochemical circuit and its potential relative to the sensing and reference electrode is not fixed by the circuit. Under quiescent conditions the cell is drawing a very small current and the counter electrode will be only a few mV more negative than the reference electrode. When an oxidisable gas is detected the cell current rises and the counter electrode polarises negative with respect to the reference electrode. (For a reducible gas e.g. Cl_2 or NO_2 the situation is reversed, with the counter electrode becoming more positive). Whilst the cell current stabilises very quickly the counter electrode polarises quite slowly and may continue to drift even though the sensor signal is stable. This is quite normal. The maximum counter electrode polarisation likely to be met in practice is 300-400mV with respect to the reference electrode.

Choice of Integrated Circuits

1) IC1 - The feedback amplifier should have either a low offset (< 1mV) or have its offset nulled out. The size of any resulting offset will affect the time taken for the output to stabilise when the circuit is first switched on. Any slow drift of offset with temperature once the circuit is turned on is unimportant. The Texas Instrument OP-07 or Intersil 7650 are both suitable.

2) IC2 - This has to measure a very small (μV) signal across the load resistor, hence the need for a high quality low offset amplifier here. The ICL 7650 is ideal for this purpose.

3) IC3 – If used, the filter amplifier can be any general purpose type.

Equivalent Integrated Circuits

INTERSIL	ICL 7650 CPD (14 pin) ICL 7650 CTV (8 pin)
TELEDYNE	TSC 7650 CPD (14 pin) TSC 7650 CPA (8 pin)
LINEAR TECHNOLOGY	LTC 1052 CN (14 pin) LTC 1052 CN8 (8 pin)

Teledyne also make a low current (200μA) version [TSC 900 ACPD (14 pin) or TSC 900 ACPA (8 pin)] with a slightly higher offset voltage (5μV) which may be more suitable for battery powered applications.

© City Technology Ltd.

FIGURE 1. CTL SULPHUR DIOXIDE SENSOR TYPE 3ST OUTPUT CHANGES WITH TEMPERATURE.

FIGURE 2. CTL SULPHUR DIOXIDE SENSOR TYPE 3SF
OUTPUT CHANGES WITH TEMPERATURE

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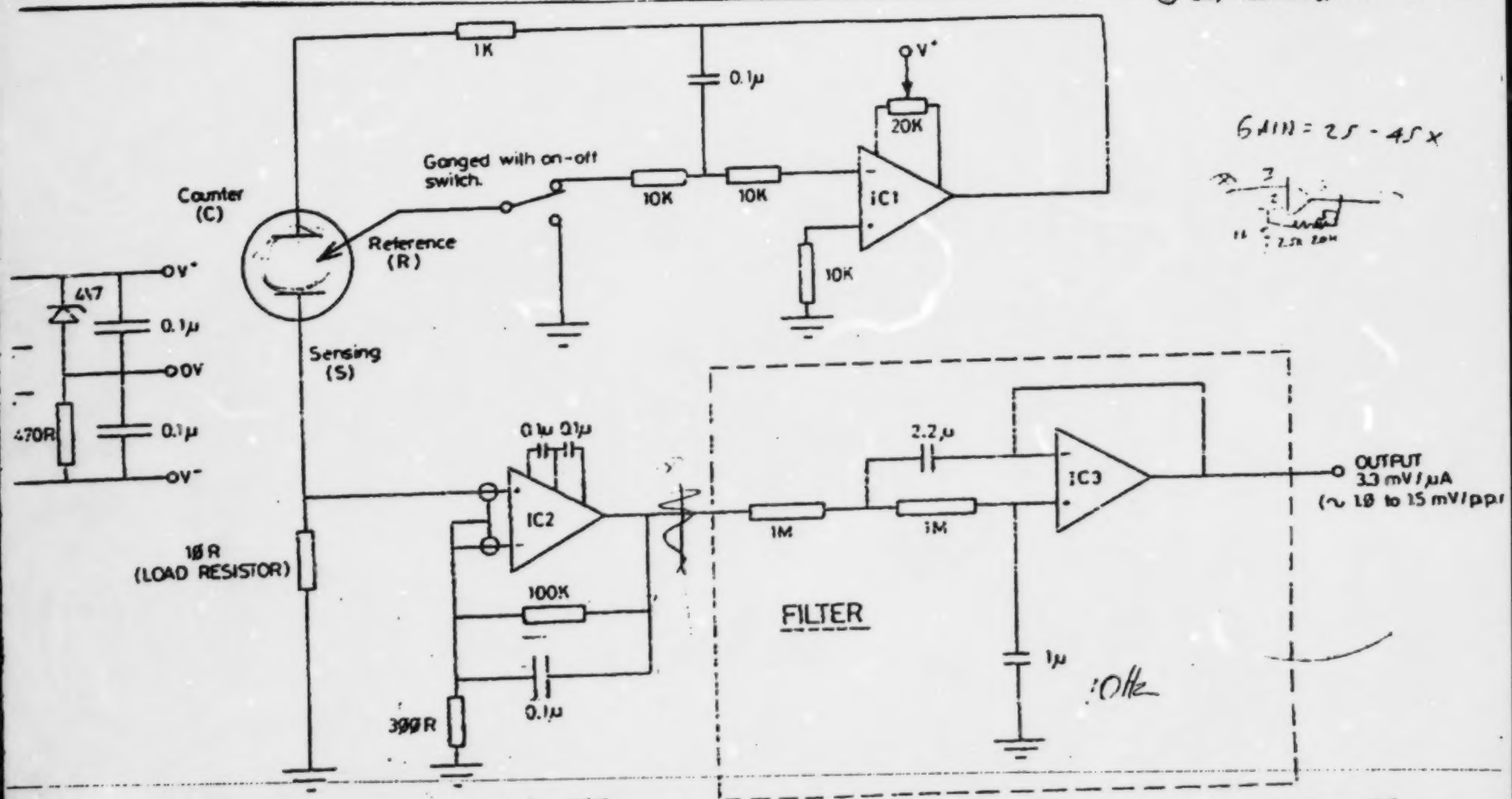


GAIN = 25 - 45 x

4-20 mA

0-1V

NOTES – IC 1 AND IC3 : OP-07 TEXAS INSTRUMENTS (OR EQUIVALENT).
IC 2 : ICL 7650 CPD INTERSIL (OR EQUIVALENT).
DELETE FILTER FOR QUICKER START UP

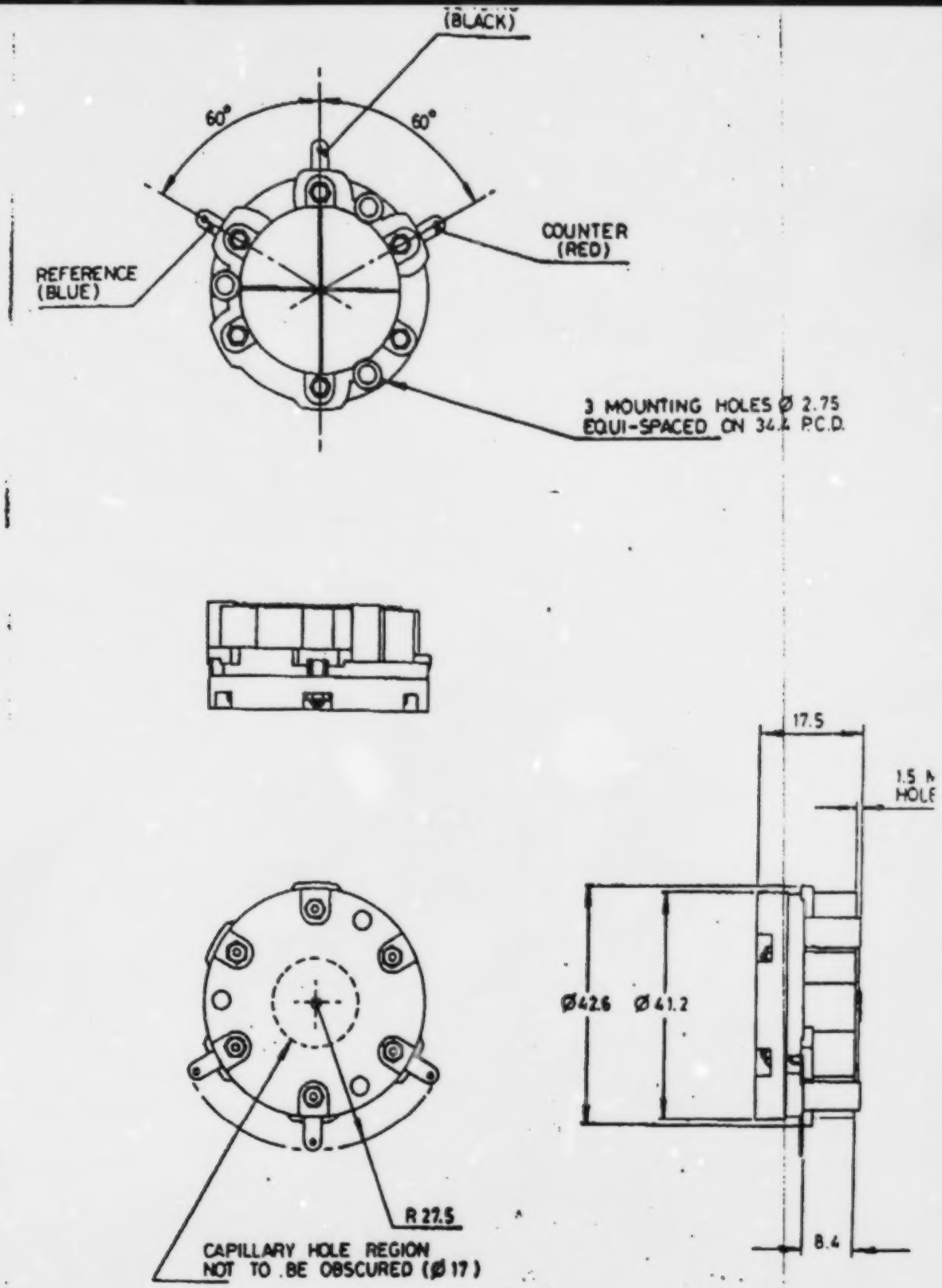
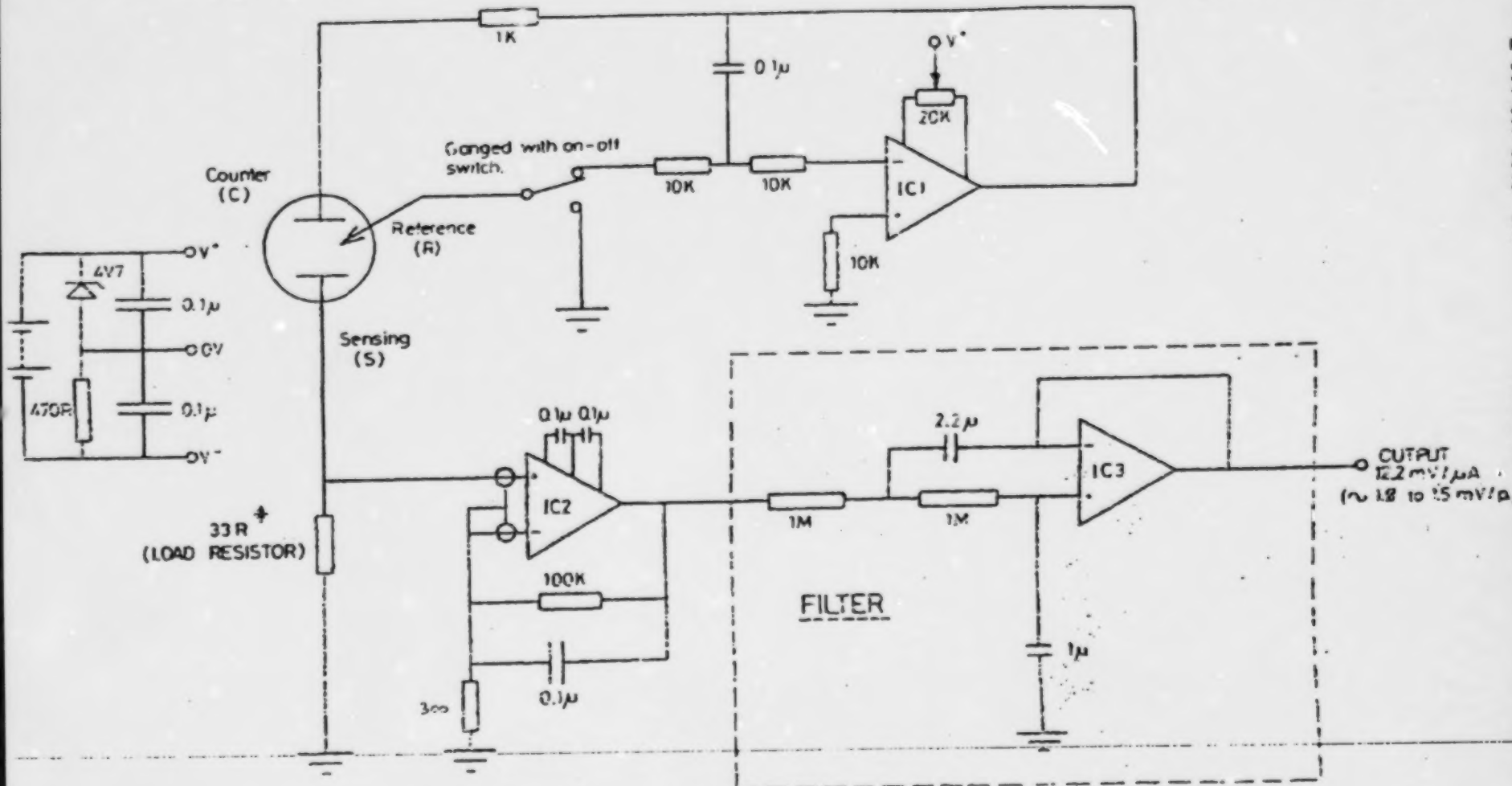


Figure 5 3SF(S) & 3ST(S) Sulphur Dioxide Sensors. Outline dimensions

© City Technology Ltd. 1985



* SWITCH LOAD RESISTOR TO 3.3R TO MEASURE ABOVE 2000 ppm.

NOTES— IC 1 AND IC3 : OP-07 TEXAS INSTRUMENTS (OR EQUIVALENT).

IC 2 : ICL 7650 CPD INTERSIL (OR EQUIVALENT).

APPENDIX B

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LETTER OF REQUEST

THE UNIVERSITY OF BRITISH COLUMBIA
DEPT. OF MINING AND MINERAL PROCESS ENGINEERING
6350 STORES ROAD
VANCOUVER, B.C., CANADA
V6T 1W5

February 2, 1988

Calibrated Instruments Inc.
731 Saw Mill River Road
Ardsley, N.Y. 15020
USA

Dear Sir/Madam:

Re: SO_2 Detectors

We are investigating SO_2 monitors for use in underground mine studies into secondary sulphide ignitions. The range required is 0 to 10 ppm in temperatures of 0 to 30° C. The ambient atmosphere will contain CO_2, CO, NO, NO_2 and may have relatively high humidity.

The instruments will be exposed to high dust levels and must be capable of prolonged operation without recalibration. The preferred output is for datalogger collection and the ability of the instrument to operate from battery power is a decided advantage.

We are interested in obtaining details of your instruments which would be suitable for this application, together with an approximate price.

Yours truly,

Dr. A. E. Hall
Assistant Professor - MMPE

/jm

3aeh-7.ltr

APPENDIX C

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SELECTED DETECTORS MANUFACTURERS REPLIES

THE UNIVERSITY OF BRITISH COLUMBIA
DEPT. OF MINING AND MINERAL PROCESS ENGINEERING
6350 STORES ROAD
VANCOUVER, B.C., CANADA
V6T 1W5

February 2, 1988

Process Analyzers Inc.
3 Headly Place
Fallsington, Pa. 19054
USA

Dear Sir/Madam:

Re: SO_2 Detectors

We are investigating SO_2 monitors for use in underground mine studies into secondary sulphide ignitions. The range required is 0 to 10 ppm in temperatures of 0 to 30° C. The ambient atmosphere will contain CO_2, CO, NO, NO_2 and may have relatively high humidity.

The instruments will be exposed to high dust levels and must be capable of prolonged operation without recalibration. The preferred output is for datalogger collection and the ability of the instrument to operate from battery power is a decided advantage.

We are interested in obtaining details of your instruments which would be suitable for this application, together with an approximate price.

Yours truly,

Dr. A. E. Hall
Assistant Professor - MMPE

/jm

PAI Titrilog II
Info received
23/2/88

3aeh-7.1tr

PROCESS ANALYZERS, INC.
8 HEADLEY PLACE, FALLSINGTON, PENNSYLVANIA 19054
215 - 736-2596 TWX 510 - 667-3562

February 10, 1988

Dr. A.E. Hall
The University of British Columbia
Dept. of Mining and Mineral Process Eng.
6350 Stores Road
Vancouver BC Canada V6T1W5

Re: SO_2 Detectors

Dear Dr. Hall:

Thank you for your letter dated February 2, 1988.

The PAI Titrilog III is excellent for monitoring SO_2 at low levels and with little maintenance. It used the caulometric principle of reducing bromine in solution and measuring the current necessary to maintain the voltage of the cell. It runs for long periods with no attention.

The titration cell of the Titrilog III is maintained at 35°C so the temperature range of 0 to 30°C is ideal. We will, of course, have to put in a filter to remove the dust. We can put in a large filter, but it will require occasional cleaning. We need to have a description of the dust to properly design a filter system.

If no reduced sulfur compounds are present, there is no need for a scrubber. If sulfide and mercaptans can be present, we can remove them with one of our solid state scrubbers which last indefinately without replacement. There is a variety of scrubbers and we need a definition of the problem if one exists. COS and CS_2 do not interfere.

The attached quote gives the price of the Titrilog and various options. If AC power is available, it is desirable to power it that way as batteries require regular re-charging.

If we can help further, please call.

Very truly yours,

PROCESS ANALYZERS, INC.

Harold V Carter

HAROLD V. CARTER
PRESIDENT

HVC:et
Encs.
cc: George V. Holby

PROCESS ANALYZERS, INC.
8 HEADLEY PLACE, FALLSINGTON, PENNSYLVANIA 19054
215 - 736 - 2596 TWX 510 - 667 - 3562

Customer's Reference	Date Quoted	Reference No.
Letter 2-2-88	2-10-88	3331

Dr. A.E. Hall
The University of British Columbia
Dept. of Mining and Mineral Process Eng.
6350 Stores Road
Vancouver BC Canada V6T1W5

This quotation is subject to the standard conditions of sale and is valid for 30 days only.

Prices quoted are F.O.B.
Fallsington, Pennsylvania
U.S.A.

By _____
Harold V. Carter

Estimated shipment 90 days after receipt of order

Item No.	Quan.	PAI No./Description	Unit Price US $	Total Price US $
1	1	Model 26-105 TITRILOG III MONITOR to detect SO_2 in air. *0-10 ppm full scale. *One stream. *One component. *Local readout. *General purpose area. *Two Operation & Maintenance Manuals.	$8,690.00	$8,690.00

Terms: Letter of Credit

QUOTATION

Item No.	Quan.	PAI No./Description	Unit Price U.S.$	Total Price U.S.$
		OPTIONS:		
A	As Req.	Installation & Start-Up Assistance.	$750.00/day plus travel and living expenses at cost.	
B	1	4-20 ma signal.	$320.00	
C	1	Sample Pump.	$365.00	
D	1	H_2S or Reduced Sulfur Trap.	$175.00	
E	1	High Level Alarm, adjustable.	$275.00	
F	1	Strip Chart Recorder: *4" Strip Chart. *0.0 to 10.0 mv full scale.	$1090.00	
G	1	Battery to power the Titrilog.	$480.00	
H	1	Permeation Tube Calibration Apparatus.	$3135.00	

STANDARD CONDITIONS OF SALE

DELIVERY:

Unless otherwise specifically provided, shipment will be scheduled after acceptance of this order in conformance with the Buyer's requirements, as far as possible, but subject to priority and scheduling regulations, changes in production schedules, export or other license requirements, and government allocations and directives. Seller will make every effort to keep the Buyer informed as to the probable shipping date, but postponement of delivery or failure to give notice of delay will not, in any way, render the Seller liable or constitute grounds for cancellations.

Seller will use its best efforts to deliver as specified herein, but shall not be liable for delays in delivery occasioned by force majeure or any cause beyond its control, including but not limited to war, labor difficulties, riot, fire, flood, earthquake, windstorm, acts or defaults of common carriers, governmental laws, acts or regulations or any other occurrence whether or not similar in character to the foregoing, beyond Seller's reasonable control. Any such delay shall effect a corresponding extension of delivery date.

Shipments made F.O.B. Seller's Plant shall be at the risk of the Buyer, who shall make all claims to the carrier in the event of damage to shipped material or losses in transit. Buyer shall notify Seller in writing relative to any shortage, within ten (10) days from receipt of shipment.

WARRANTY:

Seller warrants that the products to be delivered pursuant to this quotation will be as described herein, that no valid applicable statute has been violated in the manufacture and sale of such products, and that Seller has title to and the right to sell the same. No other warranty is given or shall be implied. Notice of any claim of breach of warranty shall be given to Seller immediately on discovery, and Seller shall thereupon correct any such breach by repair or replacement without charge, F.O.B. Seller's Plant. The liability of the Seller arising out of the supplying of said products, whether based on warranty or otherwise, shall in no case exceed the cost of said product, and all such liability shall terminate three months after shipment from Seller's Plant. The foregoing warranty does not apply to vacuum tubes, batteries, lamps, diodes or transistors; no warranty whatsoever is made with respect to these items, and Seller does not agree to repair or replace them.

TAXES:

The Seller's prices do not include sales, use, excise or other state, federal or municipal taxes. Consequently, in addition to the price specified herein, the amount of any present or future sales, use, excise or other tax applied directly to the sale hereunder shall be paid by the Buyer, or in lieu thereof the Buyer shall provide a tax exemption certificate acceptable to the taxing authorities.

CANCELLATION:

The Buyer may cancel his order only upon payment of reasonable cancellation charges which shall take into account expenses already incurred and commitments made by the Seller.

Seller may cancel the order in the event that Buyer becomes bankrupt or insolvent or makes an assignment for benefit of creditors.

PATENTS:

Seller shall not be responsible for patent infringement except that if the goods ordered are customarily sold to others by Seller, Seller shall defend any suit brought against the Buyer so far as based on a claim that any product or part thereof furnished under this agreement constitutes an infringement of United States Letters Patent, provided that Buyer notifies Seller of the institution of such suit within ten (10) days after service of process on Buyer. Seller shall control the defense of such suit and shall bear the expenses of such defense. Seller's liability to the Buyer, including the expenses of such suit, shall be limited to the total selling price of the products hereunder.

PAYMENTS:

Standard terms of payment are net cash 30 days following shipment, unless otherwise specifically provided herein. However, as its option, the Seller may require full or partial payment in advance of shipment. On overdue accounts, interest will be charged at the rate of 1% per month. In case of partial shipments, pro rata payments shall become due as shipments are made. If shipments are delayed by Buyer, payments shall become due at time Seller is prepared to make shipment. In the event of the failure of the Buyer to make payments for any installment of goods when due, the Seller may withhold further delivery until the default has been remedied or may require that subsequent deliveries be paid for in cash upon delivery. Material held for Buyer shall be at risk and expense of Buyer.

DAMAGES:

In no event shall any claim for consequential damages be made by either party.

TECHNICAL SPECIFICATIONS
3331
THE UNIVERSITY OF BRITISH COLUMBIA

I. SCOPE

A. This Technical Specification covers the design and installation requirement of a packaged process SO_2 Monitor System for automatic sampling, measuring and presenting the composition data of samples withdrawn from the points described below.

B. This specification provides for PAI to perform necessary application engineering for the proper installation and operation of an analyzer system which automatically withdraws, conditions and identifies the selected components of the sample stream.

II. GENERAL

A. Mounting Equipment

The analyzer equipment shall be bench mounted and suitable for general purpose location.

B. Panel Mounted Equipment (Recorder Only)

Panel instruments shall be located on a control room panel.

C. Power

Power supply by purchaser shall be unregulated 110 V, 60 Hz, single phase, 50 watts, 150 watts with electric pump option.

D. Assembly

The analyzer system will be completely assembled, piped, wired and tested.

TECHNICAL SPECIFICATIONS
3331
THE UNIVERSITY OF BRITISH COLUMBIA

III. PROCESS MONITOR

A. Sample Data

1. Source — Air

Physical Data

State	Gas
Temperature, ^{o}C	0 - 30
Pressure	Atmospheric*
Solids	Present

*Assumed Values

Composition: (Assumed to be air)

SO_2	0 - 10

2. Readout Range: — ppm

SO_2	0 - 10

Field Adjustable

TECHNICAL SPECIFICATIONS
3331
THE UNIVERSITY OF BRITISH COLUMBIA

III. PROCESS MONITOR (continued)

B. Monitor:

Type: PAI 26-105 Monitor suitable for gas sampling.

Analyzer: The Analyzer shall continuously monitor SO_2 in a gas stream. Silver metallic gauge Scrubbers will hold back reduced sulfur if needed. Without scrubber, analyzer will give total sulfur.

Automatic Sampling: Pressure regulator, filter, valves and flow regulator shall be provided to provide a sample flow of approximately 200 cc/min. to the monitor. Manual valving for calibration.

Electrical Classification: General Purpose.

Mounting: PAI Analyzer to be bench mounted in an area protected from the weather.

C. Data Readout:

Local dial readout.

0 - 5 mv signal for recorder option.

4 - 20 ma, optional.

IV. SAMPLING

The sample system will be furnished completely piped, valved and wired with necessary accessories to furnish a complete pre-packaged sampling system. All wetted parts to be stainless steel, or inert polymer.

A. Sample Conditioner System

PAI Sampling System, set up for one stream, contains:

1 Pump (air-aspirator or rotary vane)
1 Final Filter
1 Flowmeter with needle valve
1 Calibration Select Stream Valve

Electrical Classification: General Purpose.

Mounting: Sample System shall be integrally mounted with the monitor.

TECHNICAL SPECIFICATIONS
3331
THE UNIVERSITY OF BRITISH COLUMBIA

V. ACCESSORIES

Manuals:

PAI will furnish two copies of the Operation and Maintenance Manual. Complete drawings of all systems with part numbers will be included. Recommended spare parts will be listed. Additional manuals available as an option.

VI. TECHNICAL SERVICE

PAI will furnish application engineering service to effect features and in-factory checks indicated. PAI will train personnel of the customer in operation and maintenance at the PAI Factory at the customer's option.

VII. FIELD SERVICES: At Customer's Option

PAI will furnish a Service and/or Application Specialist to assist with any problems that may occur in installation and start-up. PAI also will train personnel to be connected with the maintenance of the instrument.

VIII. BATTERY: At Customer's Option

Two sets of bateries and one recharger will be supplied at customer's option.

THE UNIVERSITY OF BRITISH COLUMBIA
DEPT. OF MINING AND MINERAL PROCESS ENGINEERING
6350 STORES ROAD
VANCOUVER, B.C., CANADA
V6T 1W5

February 2, 1988

CEA Instruments Inc.
15 Charles Street
Westwood, NJ 07675
USA

Dear Sir/Madam:

Re: SO_2 Detectors

We are investigating SO_2 monitors for use in underground mine studies into secondary sulphide ignitions. The range required is 0 to 10 ppm in temperatures of 0 to 30° C. The ambient atmosphere will contain CO_2, CO, NO, NO_2 and may have relatively high humidity.

The instruments will be exposed to high dust levels and must be capable of prolonged operation without recalibration. The preferred output is for datalogger collection and the ability of the instrument to operate from battery power is a decided advantage.

We are interested in obtaining details of your instruments which would be suitable for this application, together with an approximate price.

Yours truly,

A E Hall

Dr. A. E. Hall
Assistant Professor - MMPE

/jm

3aeh-7.1tr

CEA Instruments,Inc.
16 Chestnut Street • P.O. Box 303
Emerson, New Jersey 07630 U.S.A.
Phone 201-967-5660 • Telex 642128

March 24, 1988

Dr. A.E. Hall
THE UNIVERSITY OF BRITISH COLUMBIA
Dept. of Mining and Mineral Process Engineering
6350 Stores Road
Vancouver, B.C., CANADA
V6T 1W5

Dear Dr. Hall:

Thank you for your interest in CEA Instruments and your recent letter.

We are pleased to enclose the literature you requested.

If you require additional information, have any questions which require an immediate answer, or need assistance in placing an order, please give me a call.

Sincerely,

M H Adelman

Martin H. Adelman
General Manager

MHA/mf
enc.

CEA Instruments, Inc.
16 Chestnut Street • P.O. Box 303
Emerson, New Jersey 07630 U.S.A.
Phone 201-967-5660 • Telex 642128

PRICE LIST

SERIES-7

Portable Toxic Gas Monitor, with digital read out and audible/visual alarm, micro processor controlled, battery operated, self contained, complete with carrying case, particulate filter, sampling probe and line $1,995.00

OPTIONS:

Ni-Cad Batteries, set of four	$ 48.00
Ni-Cad Battery Charger	$ 24.00
AC Power Supply	$ 185.00

When ordering please specify one gas from following:

AS-7	Arsine	(AsH_3)	0-1.00 ppm full scale	(0.05 ppm per digit)
BH-7	Diborane	(B_2H_6)	0-30.0 ppm	(0.5 ppm)
CO-7	Carbon Monoxide	(CO)	0-500 ppm	(5.0 ppm)
CL-7	Chlorine	(Cl_2)	0-3.00 ppm	(0.05 ppm)
HL-7	Hydrogen Chloride	(HCl)	0-15.0 ppm	(0.5 ppm)
HS-7	Hydrogen Sulfide	(H_2S)	0-100 ppm	(0.1 ppm)
NO-7	Nitric Oxide	(NO)	0-100 ppm	(1 ppm)
ND-7	Nitrogen Dioxide	(NO_2)	0-15 ppm	(0.5 ppm)
PH-7	Phosphine	(PH_3)	0-1.00 ppm	(0.05 ppm)
SH-7	Silane	(SiH_4)	0-15.0 ppm	(0.5 ppm)
SO-7	Sulfur Dioxide	(SO_2)	0-15.0 ppm	(0.5 ppm)

TERMS: Net 30 days, F.O.B. Emerson, New Jersey

S7PL 0487

THE UNIVERSITY OF BRITISH COLUMBIA
DEPT. OF MINING AND MINERAL PROCESS ENGINEERING
6350 STORES ROAD
VANCOUVER, B.C., CANADA
V6T 1W5

February 2, 1988

Calibrated Instruments Inc.
731 Saw Mill River Road
Ardsley, N.Y. 15020
USA

Dear Sir/Madam:

Re: SO_2 Detectors

We are investigating SO_2 monitors for use in underground mine studies into secondary sulphide ignitions. The range required is 0 to 10 ppm in temperatures of 0 to 30° C. The ambient atmosphere will contain CO_2, CO, NO, NO_2 and may have relatively high humidity.

The instruments will be exposed to high dust levels and must be capable of prolonged operation without recalibration. The preferred output is for datalogger collection and the ability of the instrument to operate from battery power is a decided advantage.

We are interested in obtaining details of your instruments which would be suitable for this application, together with an approximate price.

Yours truly,

Dr. A. E. Hall
Assistant Professor - MMPE

/jm

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CALIBRATED INSTRUMENTS, INC.

731 SAW MILL RIVER ROAD
ARDSLEY, NEW YORK 10502
TELEPHONE: (914) 693-9232
TELEX: CALIB ARLY 131 423

February 19, 1988

Dr. A. E. Hall
Assistant Professor MMPE
University of British Columbia
Dept. of Mining & Mineral Process Eng.
6350 Stores Rd.
Vancouver, B.C. V6T 1W5
C a n a d a

Dear Dr. Hall,-

Thank you for your letter of Feb. 2, 1988. Enclosed please find the requested literature for various types of SO_2 Analyzers as well as approximate prices. Final prices will, of course, depend on the specific application and/or additional necessary accessories.

Sincerely,
CALIBRATED INSTRUMENTS, INC.
John Mann

Encl. a/s

JM/bl

731 SAW MILL RIVER ROAD
ARDSLEY, NEW YORK 10502
TELEPHONE: (914) 693-9232
TELEX: CALIB ARLY 131 423

CALIBRATED INSTRUMENTS, INC.

2/19/1988

SO_2 ANALYZERS

Model ULTRAGAS U3EK-SO	approx. US$ 30,500.00
Model MIKROGAS TE-SO_2	approx. US$ 17,500.00
Model MIKROGAS ME-SO_2	approx. US$ 20,630.00

SO_2-Emissionskontrolle

mit dem Analysator MIKROGAS TE-SO_2

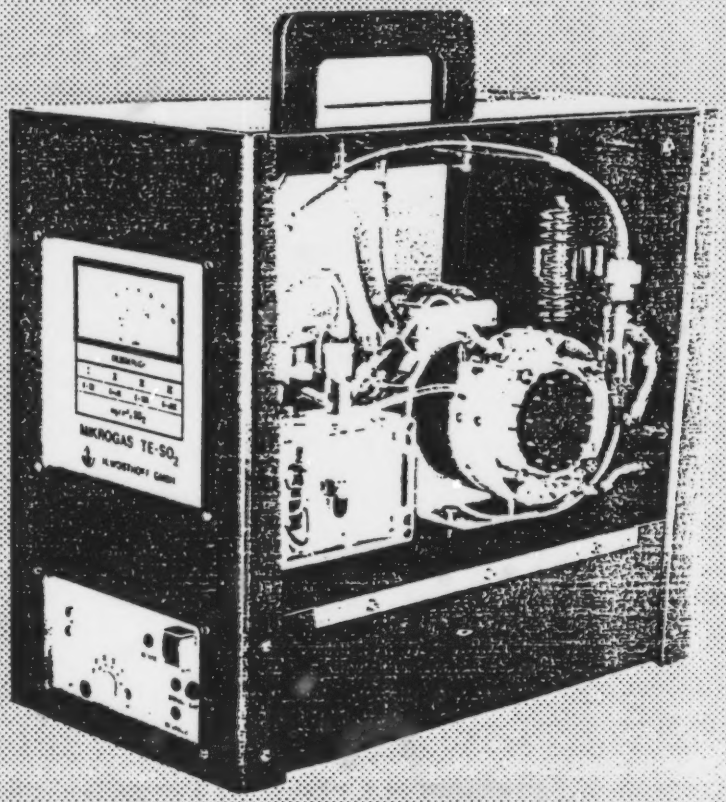
Selektives Meßverfahren

kein Wasserdampfeinfluß

keine Nullpunktsdrift

umschaltbare Meßbereiche für Einsatz bei:

Rauchgas
Abgas
Röstgas
vor REA
nach REA



H. WÖSTHOFF GMBH Meßtechnik Bochum

D-4630 Bochum 1 · Max-Greve-Straße 30 · Telefon (02 34) 5 18 14/15 · Telex 08 25 757 hwmes

SO_2-Emission Control

501 - 6.2 e

with the Analyser MIKROGAS MS-SO_2

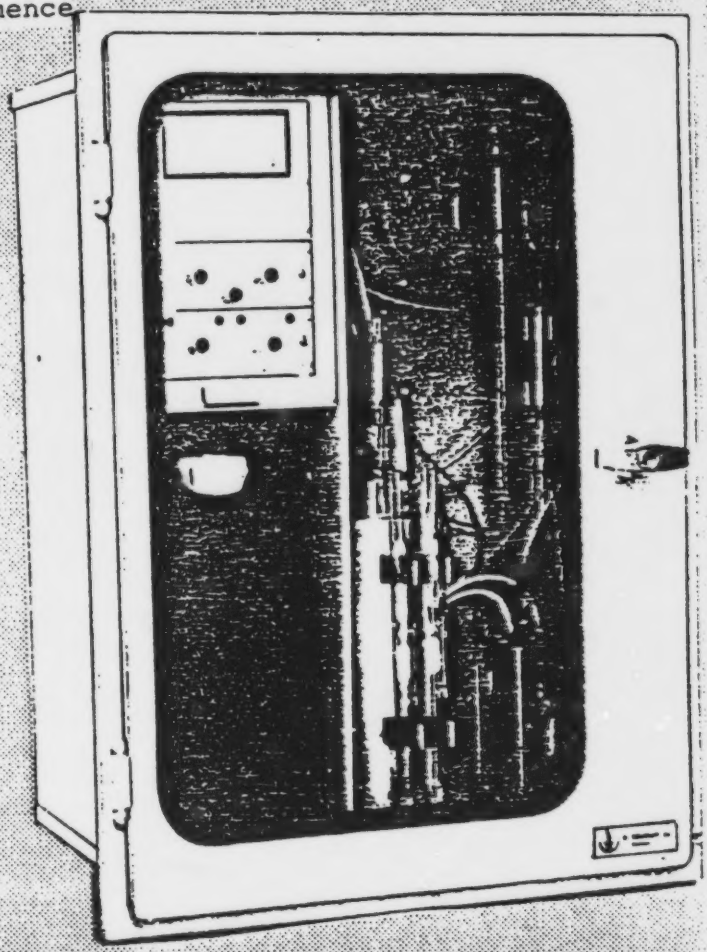
Selective
Measuring Principle

No Water Vapour Influence

No Zero Point Drift

Switchable
Measuring Ranges
for Application in:

Flue Gas
Waste Gas
Gas from Roasting
Before REA
After REA



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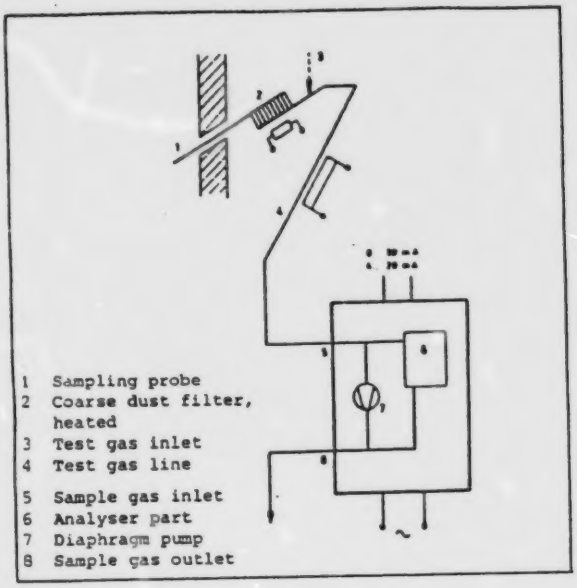

Fig. 1

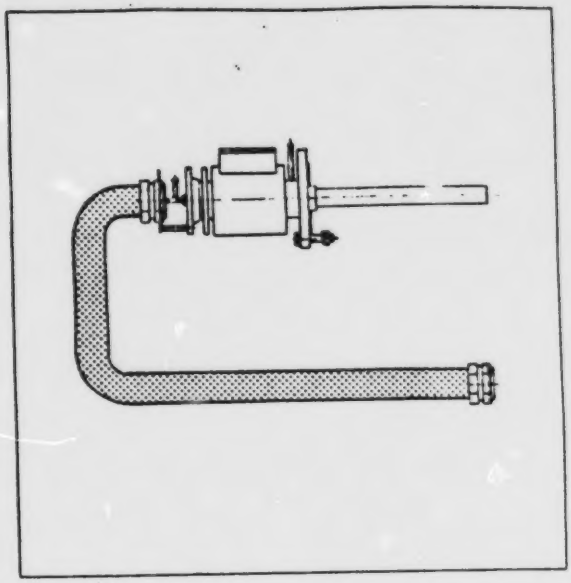

Fig. 2

Range of Application

The contamination of the atmosphere with flue gases which are detrimental to health and to plants led to the Regulation for Heavy Furnaces (GFAVO) which limits a.o. the SO_2 emissions to defined maximums in accordance with the fuels used and the furnace capacities. With the GFAVO the legislator applicates his right to require, if necessary, the modification also of old furnaces and for furnaces which are not yet included.

For the prescribed measurements and the continous recording of the SO_2-mass flow, the analyser MIKROGAS MS-SO_2 will be used for furnaces fired with pit coal, lignite, oil, and gas.

The analyser MIKROGAS MSK-SO_2 has passed the aptitude test of the 'Rheinisch-Westfälischer Überwachungsverein e.v.' (Report E 24/66 dtd. 06.01.1967) and of the 'Technischer Überwachungsverein Rheinland e.v.' (Report 800371 dtd. 15.10.1968).

Composition and Function

Total System

In accordance with the gas flow plan Fig. 1 the test gas will be sucked-in with the diaphragm pump built-in in the analyser MIKROGAS by means of the sampling probe with coarse dust filter and the test gas supply line and then delivered to the outlet of the test gas surplus. If necessary, coarse dust filter and test gas supply line will be heated to avoid the forming of condensate products.

Gas Sampling Probe

The gas sampling probe Fig. 2 consists of the sampling tube and an external ceramical filter with electric heating. It is suitable for the application in wet and dust-containing gases at temperatures up to 400° C. For the gas extraction for hand analysis and for the feeding of test gas, separate gas connections are provided.

Test Gas Supply Line

For the test gas transfer from the sampling probe to the analyser a synthetic hose pipe for installation in protected rooms can be used in simple cases. If a fall below dew point should be avoided in the test gas line, then a PTFE-line will be used which keeps the temperature to about 80 - 90° C with a self-regulating heating. The thermal insulation and the water-proof protection pipe made of PVC allow an installation also in humid rooms.

Analyser

The gas analyser MIKROGAS uses as measuring effect the change of the electrolytic conductivity of a reaction solution. The test gas will be continously contacted with a hydrogen-peroxide solution. Thus, the sulfur dioxide contained in the test gas will be absorbed and oxidized to sulfurous acid. The so caused change of the electrical conductivity of the reaction solution is a direct indication for the sulfur dioxide concentration of the test gas.

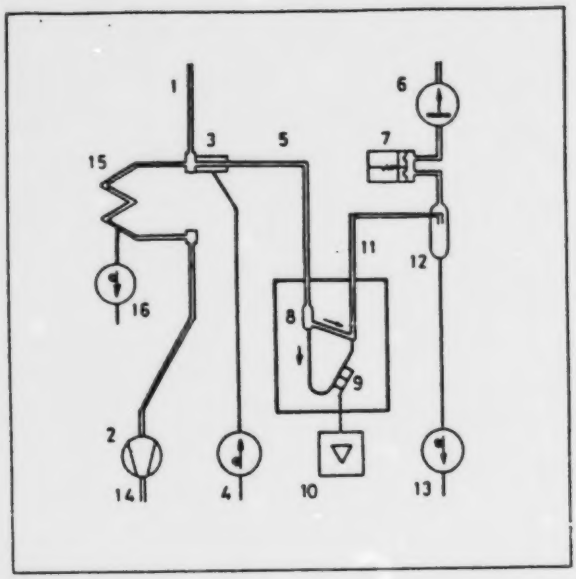

Fig. 3

Technical Data:

Measuring ranges	from 0 - 50 mg/m³ SO_2 up to 0 - 100 g/m³ SO_2
Test Gas Quantity	2 l/min
Reaction Solution	VE-water 5 µS/cm + H_2O_2 + wetting agent
Storage Vessel	11 l for working period 1 month at 0.2 ml/min solution delivery
90 % Adjustment Time	about 80 sec at 0.4 ml/min about 160 sec at 0.2 ml/min
Ambient Temperature	2° C...40° C
Steel Plate Casing	485 x 670 x 395 mm deep
Weight	about 35 kg

Fig. 3 shows the function scheme of the analyser MIKROGAS. The test gas will be sucked-in in surplus with diaphragm pump 2 through gas inlet 1. The measuring gas necessary for reaction will be taken from the test gas flow with a wet sampling head 3 and then, together with the reaction solution delivered through pump 4, sucked through line 5 to the measuring cell whereby this line serves as reaction line.

The delivery and the quantity-exact dosing of the measuring gas is effected by pump 6 to which a flow control device 7 is added. With the flow control device, the influence of possible pressure fluctuations at the test gas taking point will be compensated.

After gas and solution having passed the reaction line, the measuring gas will be separated from the solution in the gas separator 8 of the measuring cell and then the electrolytical conductivity of the solution will be measured in the electrode line 9 and then fed to the indicator and the signal outlet via amplifier 10 as impressed current 0 - 20 mA/4 - 20 mA. Because of the conductimetric measuring principle the measuring signal corresponds directly to the SO_2-mass concentration related to 273 K and 1013 mbar and dry measuring gas.

Through line 11, solution and measuring gas together leave the measuring cell. From the gas-liquid separator 12, the solution will be sucked-off in the under part with pump 13 whereas the measuring gas will be fed to pump 6 via the upper outlet.

If necessary, reactive components which could possibly influence the measurement, will be deleted from the test gas in a short added condensation and absorption line 15. The condensate will be fed into a condensate vessel or continously sucked-off with pump 16.

Measuring Method without Vapour Influence

In contrast to other SO_2 emission systems, the conductivity method is suitable for the direct measurement of test gas with a high water vapour part also without an added test gas cooler.

If a measuring gas cooler is used for water vapour condensation, then surprisingly high faulty measurements because of SO_2-losses in the produced condensate can occur with test gases with high water vapour quantities. These faulty measurements are the more grave the lower the SO_2-contents are, e.g. after wet washers. At dew point temperatures about 70° C in the test gas, the volume of the water vapour is already 25 %, so that dry measuring methods with heated bulbs are not suitable for direct measurements of the SO_2-mass concentration, related to nominal volume (dry), because of the water vapour volume fault.

With the analyser MIKROGAS the condensation of the water vapour of the test gas is effected simultaneously with the absorption of the SO_2 in the reaction solution. With the chosen ratio of the delivery volumes of gas and reaction solution, there are no faults at the zero point even if there are very large contents of water vapour in the test gas. The deviation of the sensibility is irrespectively from the measured value even for dew point temperatures up to 70° C below 2 % of the corresponding measured value, related to dry gas.

Other Interfering Components

Other relevant components of the test gas do not change the conductivity of the reaction solution, e.g. NO_x, CO_2, CO, O_2, KW, H_2SO_4-Aerosol, or they will be selectively eliminated in a condensation and absorption line which will be added if necessary, e.g. HCl, H_2S, Cl_2, NH_3, SO_3,

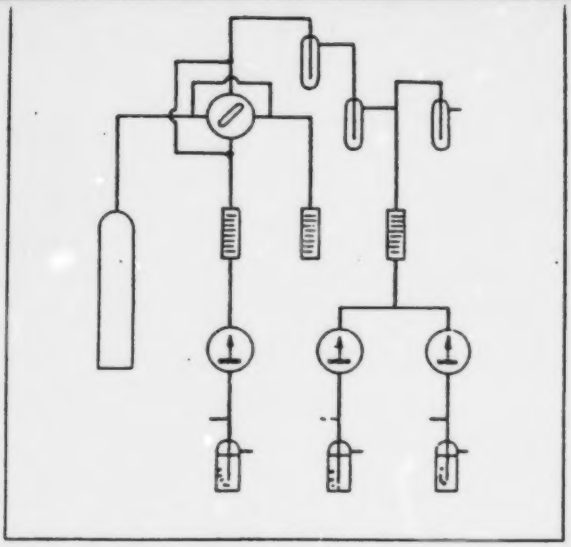

Fig. 4

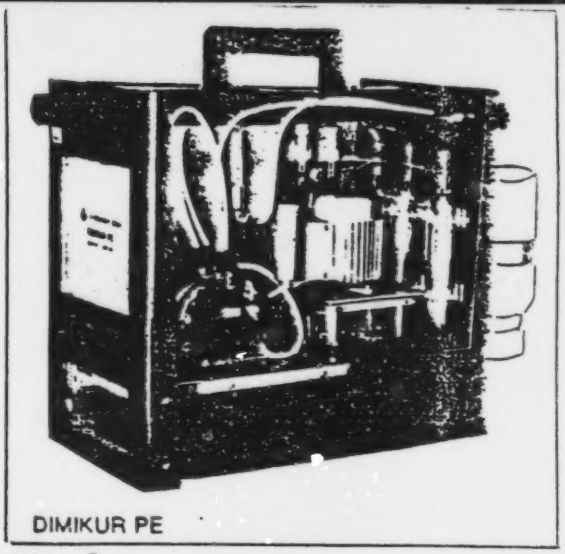

Fig. 5

Production of Test Gases

For calibration and testing of emission gas analysers test gases with different components in several graduated concentrations are required. In practice, the dynamic test gas production with pure gas or a predilution directly at the installation place of the gas-analysers with the gas dosing device DIMIKUR has proven effective, see VDI-rule 3490, sheet 7E.

With the dynamic production of e.g. SO_2 and HCl-containing test gases, only the carrier gas flow will be produced with the well-known gas mixing pump DIGAMIX. The admixture will periodically and in constant gas quantities be injected into the carrier gas flow by a dosing device DIMIKUR. By using the dosing device DIMIKUR faults because of possible absorptions of the admixture in the gas mixing pumps DIGAMIX can be avoided.

Because of the chosen carrier gas volume flow and the dosing volume for the admixture, test gas concentrations up to the low ppm-range are possible in one dilution step. The produced test gas volume flow of about 2.5 l/min is sufficient for the calibration of the normally used emission gas analysers, also if the test gas is fed at the extraction line.

The different concentrations of the admixture in the test gas can be set quickly and simply by variation of the number of injections/minute. The adjustment of the impuls number from 0 - 20 is effected in 15 steps. With the disposable dosing volumes of 40 µl, 100 µl and 400 µl per impulse, the large range of the emission concentrations to be measured for the different detrimental gases is well covered. The obtainable volume concentrations and the mass concentration for some common detrimental gases are indicated in the undermentioned table.

As carrier gases, non-corrosive pure gases or purified air can be used, which must, however, be brought to a dew point temperature of $< -20°$ C by means of a cooling trap or other suitable means for the production of HCl-test gases. The three systems for the carrier gas delivery of the gas mixing device DIMIKUR PE enable also a defined carrier gas composition of the different components: e.g. about 3 % O_2, 21 % CO_2 and 76 % N_2.

	Dosing Volume 40µl	Dosing Volume 100µl	Dosing Volume 400µl
	15 - 300ppm	40 - 740ppm	150 - 3000ppm
SO_2	44 - 870	110 - 2170	440 - 8680
HCl	25 - 480	60 - 1200	250 - 4840
NO	20 - 400	50 - 1000	200 - 4000
CO	20 - 370	50 - 930	180 - 3700

Data in vol ppm and mg/m³ at a carrier gas flow of about 2.5 l/min

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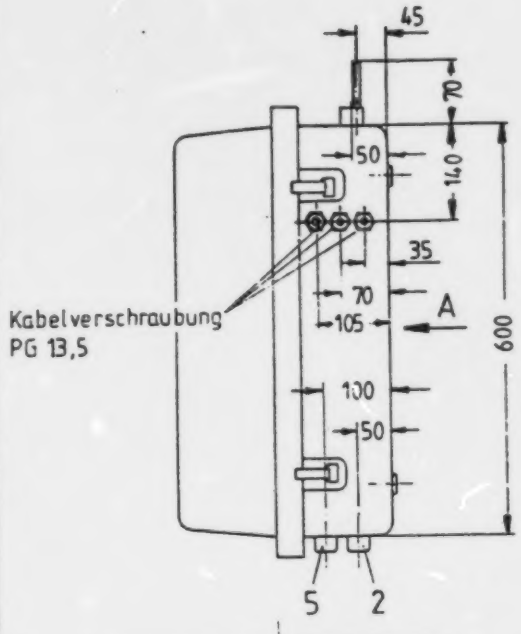
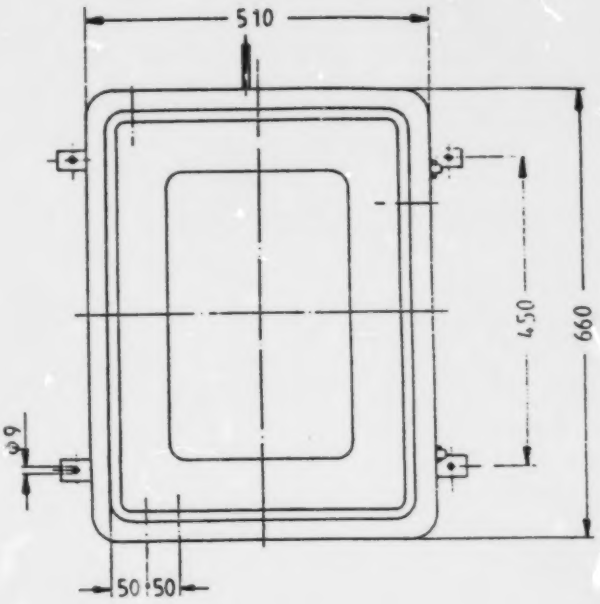
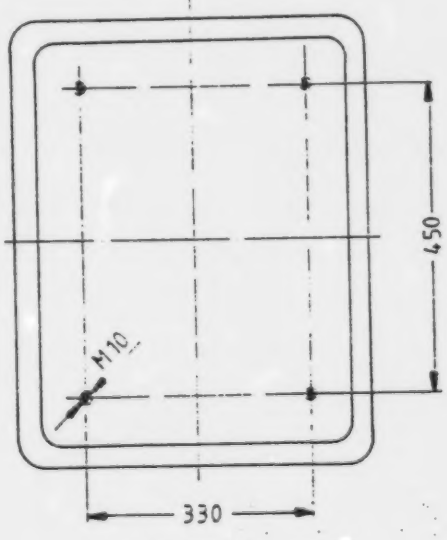
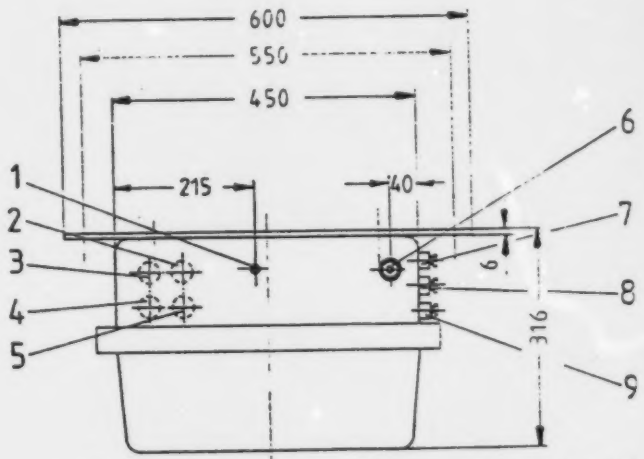


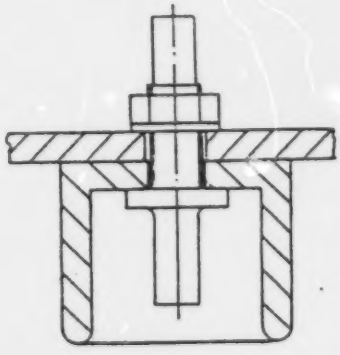




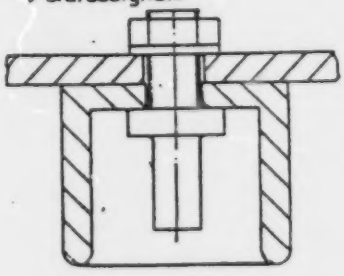
Ansicht A
ohne Befestigungslaschen



1 Meßgas-Eingang / Rohr 8x1 Werkst.-Nr. 1.45
2 Reaktionslösung-Eingang
3 Meßgas-Ausgang
4 Instrumentenluft-Eingang
5 Ausgang-Reaktionslösung+Restgas
6 Instrumentenluft-Ausgang
7 Netz 220 V~
8 Signalausgang mA
9 Statussignale



Anschluß 2,4,5

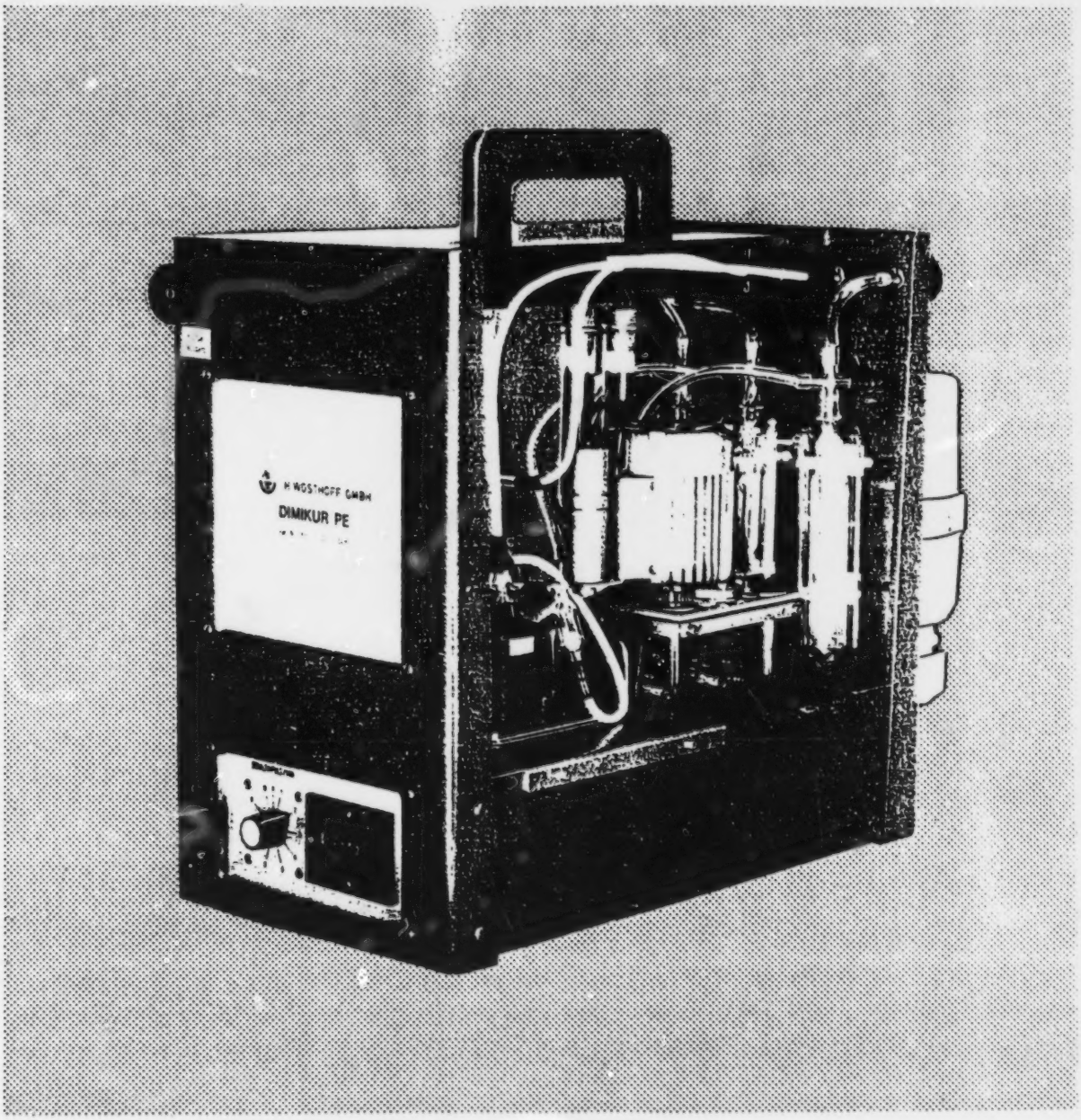


Anschluß 3,6

Datum 2.9.87 gez Ba gepr ..... Ersatz für ..... Ersetzt durch .....

DIMIKUR PE

zur Prüfgasherstellung



H. WÖSTHOFF GMBH Meßtechnik Bochum

D-4630 Bochum 1 · Max-Greve-Straße 30 · Telefon (02 34) 5 18 14/15 · Telex 08 25 757 hwmes

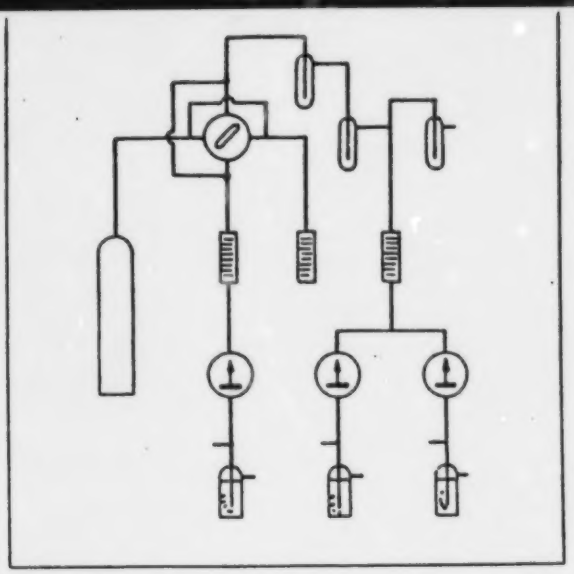


Fig. 4

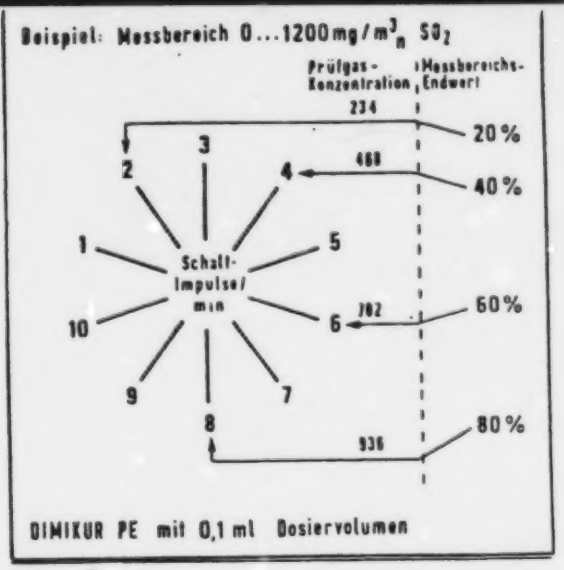


Fig. 5

Production of Test Gases

For calibration and testing of emission gas analysers test gases with different components in several graduated concentrations are required. In practice, the dynamic test gas production with pure gas or a predilution directly at the installation place of the gas-analysers with the gas dosing device DIMIKUR has proven effective, see VDI-rule 3490, sheet 7E.

With the dynamic production of e.g. SO_2 and HCl-containing test gases, only the carrier gas flow will be produced with the well-known gas mixing pump DIGAMIX. The admixture will periodically and in constant gas quantities be injected into the carrier gas flow by a dosing device DIMIKUR. By using the dosing device DIMIKUR faults because of possible absorptions of the admixture in the gas mixing pumps DIGAMIX can be avoided.

Because of the chosen carrier gas volume flow and the dosing volume for the admixture, test gas concentrations up to the low ppm-range are possible in one dilution step. The produced test gas volume flow of about 2.5 l/min is sufficient for the calibration of the normally used emission gas analysers, also if the test gas is fed at the extraction line.

The different concentrations of the admixture in the test gas can be set quickly and simply by variation of the number of injections/minute. The adjustment of the impuls number from 0 - 20 is effected in 15 steps. With the disposable dosing volumes of 40 µl, 100 µl and 400 µl per impulse, the large range of the emission concentrations to be measured for the different detrimental gases is well covered. The obtainable volume concentrations and the mass concentration for some common detrimental gases are indicated in the undermentioned table.

As carrier gases, non-corrosive pure gases or purified air can be used, which must, however, be brought to a dew point temperature of $\leq -20°$ C by means of a cooling trap or other suitable means for the production of HCl-test gases. The three systems for the carrier gas delivery of the gas mixing device DIMIKUR PE enable also a defined carrier gas composition of the different components: e.g. about 3 % O_2, 21 % CO_2 and 76 % N_2.

	Dosing Volume 40µl	Dosing Volume 100µl	Dosing Volume 400µl
	15 - 300ppm	40 - 740ppm	150 - 3000ppm
SO_2	44 - 870	110 - 2170	440 - 8680
HCl	25 - 480	60 - 1200	250 - 4840
NO	20 - 400	50 - 1000	200 - 4000
CO	20 - 370	50 - 930	180 - 3700

Data in vol ppm and mg/m³ at a carrier gas flow of about 2.5 l/min

ULTRAGAS - U3E - U3ES - U3EK - SO_2

Table of Contents

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* The indicated technical data are only for the description of the product and cannot be taken as guaranteed characteristics with regard to legal claims.

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TECHNICAL DESCRIPTION

1. Range of Application

The atmospheric pollution in areas with industrial agglomerations and in large towns requires a continous control of the atmospheric pollution. From the gaseous substances which cause atmospheric pollution sulfur dioxide (SO_2) is the most widespread as it results from the combustion of sulfurous fuels and other technical processes.

In accordance with VDI-Standard 2108 "Maximum Immission Concentration" an important task of the air analysis is the control whether the indicated limit value for sulfur dioxide will be observed.

From the various methods of the trace gas analysis the conductivity method for the registration of SO_2 in air has gained special importance as with this method also lowest concentrations of SO_2 can be determined relatively easy.

The conductivity method will be used in the chemical-physical trace gas analyser ULTRAGAS-U3E for the determination of SO_2.

The compact construction of analyser part, line recorder and integrator for measured value with printer, the high measuring accuracy, the temperature independence and the portable execution of the analyser (small dimensions of casings) makes an operation in laboratories and operating rooms possible.

The analyser ULTRAGAS-U3E is especially suitable for the operation in automatic measuring stations of air control systems as it allows a maintenance-free operation of about 2 months and as it is equipped with control devices for the signalling of the important analyser functions.

2. Particulars about SO_2

1 mg/m³ = 0.375 ppm (20° C 10^5 Pascal)

1 ppm = 2.71 mg/m³ (20° C 10^5 Pascal)

MIK_D = 0.19 ppm (0.5 mg/m³)

MAK = 5 ppm (13.5 mg/m³)

Immission valuesaccording to TAL (Technical Standard Air):

IW 1 = 0.14 mg/m³

IW 2 = 0.40 mg/m³

3. Technical Data

Possible Groups of Measuring Ranges

Range	mg/m³	mg/m³	mg/m³
I	0...0.5	0...1.0	0...2.0
II	0...1.0	0...2.5	0...5.0
III	0...3.0	0...5.0	0..10.0
	Standard Execution		

Automatical measuring range change-over for 2 measuring ranges (from I to II) is possible. The corresponding signal lamp will light up on the front plate EGMU (7).

Indicator: moving coil measuring element,
moving coil 20 mA, class 1.5, length of scale 80 mm

Time Relation (with selective filter)

Lead time t_V: 60 min

Dead time t_T: 45 s

Adjusting time $t_{90\%}$: 105 s

Admissible ambient temperature: +2...+35° C

Temperature of measuring cell (adjusted): +40° C

.../4

Calibration temperature:	20° C
Calibration pressure:	10^5 Pascal
Measuring gas pressure:	atmospheric pressure
Reaction solution:	weakly acidified H_2O_2-solution
Consumption of reaction solution:	about 6 cm³/h 11 litres - 2 months 5 litres - 4 weeks

The following measuring particulars are related to the standard measuring range of 1 mg/m³:

Trace limit: (sensibility of reaction)	0.01 mg/m³
Indicating balance: (range of fluctuation)	max. ± 0.02 mg/m³
Dispersion of zero value: within 1 month	± 0.01 mg/m³
Zero drift: within 1 month	< 0.02 mg/m³
Indicating drift: within 1 month	< 0.03 mg/m³
Absolute precision:	will be adjusted according to officially admissible methods (see VDI-Standard 2451)
Temperature error of zero point:	< ± 2 % of IW 2
Signal outlet:	0 [4] ...20 mA, max. load 250 Ohm (on application with galvanic separation and max. load 750 Ohm)
Additional signal outlet:	0 [4] ...20 mA, ≤ 2 Volt 4 mm standard clamping devices
Power supply (auxiliary energy):	220 Volt ± 10 %, 50 Hz about 100 VA (with additional attachment)

Mains receiver:	4-pole flange box Amphenol-Tuchel,type T 31 10
Connection for measuring gas and reagent:	on front side or back side
Connection for PTFE-tubing Ø 1.75/Ø 2.45:	with hose cuff D 50 3476
Connection for PTFE-tubing Ø 2/Ø 4:	with hose cuff D 50 3476-3
Material of the pieces which carry measuring gas:	PTFE, PVC, glass, plexiglass, Viton
Material of the pieces which carry reagents:	PTFE, Tygon, glass
Dimensions U3E:	drawing D 43 8034-...
Dimensions U3E (without casing):	drawing D 43 8504-...
Dimensions U3EK:	drawing D 43 9320-...
Dimensions U3EK (without casing):	drawing D 43 9321-...
Dimensions U3ES:	drawing D 43 8038-...
Weight (without reagent) U3E:	32 kg
Weight (without reagent) U3ES:	21.5 kg (Analyser) 24.5 kg (measuring part with additional attachments)
Weight (without reagent) U3EK:	———

<u>Additional attachments</u>:

Zero control:	will be made every 23 h by means of a solenoid valve which will be operated by a time switch EZSN resp. EZAN.Externally or by hand with EZRN.
Control with test gas:	dito Total time for both controls about 25 min.

.../6

Computer connection:	50-pole socket Amphenol-Tuchel, type series 17
Registration of measured value:	built-in line recorder 0...20 mA (4...20 mA)
Integration of measured value: (15, 30 or 60 min)	built-in integrator EAIW with printer PL 205/E for measured value and time
Control for the delivery of gas and solution:	built-in tracer A and B with measuring card ESGK
Control for the temperature of the measuring cell:	built-in tracer C with measuring card ESTK (also for A and B)
Control of the temperature of the selective filter:	with thermo element FH 12 measuring card ESTF (also for A, B and C)
For battery-operation:	battery, transformer 24-200 T (Sinus) inlet 24 V-, outlet 220 V, 50 Hz

4. Chemical-Physical Measuring Principle

In the trace gas analyser ULTRAGAS-U3E a continous and constant flow of the measuring gas and of the reaction solution react together in a reaction line whereby the measuring component will be absorbed in the reaction solution. The electrical conductivity power of the reaction solution will change in relation to the concentration of the measuring component (SO_2). The oxidation of sulfur dioxide will be effected in a diluted hydrogen peroxide solution of sulfuric acid in accordance with the reaction equations

$$SO_2 + H_2O \longrightarrow H_2SO_3$$

$$H_2SO_3 + H_2O_2 \longrightarrow H_2SO_4 + H_2O$$

to sulfuric acid.

Because of the high ionic mobility of the H-ions of the constituted sulfuric acid even lowest traces of SO_2 can be measured quantitatively. The difference value of the conductivity values is an index for the effected material conversion and thus for the sulfur dioxide sucked-in with the measuring gas.

With the ULTRAGAS U3E the conductivity change will be controlled in the measuring cell G by means of 2 electrode measuring lines. First, the conductivity of the reaction solution will be measured in the electrode measuring line G_1 and after effected reaction with SO_2 in the electrode measuring line G_2.

The difference of the alternative flows flowing through the 2 electrode measuring lines will be delivered to the inlets of the built-in measuring transmitter.

After preparation of the measuring signal an impressed flow of 0 [4] ...20 mA will be available as signal outlet.

For the high precision and reliability of the measurement several provisions are made. The temperature influence on the conductivity will be eliminated by the arrangement of the electrodes and reaction lines in a temperature-controlled oil bath.

.../8

The quantity of the measuring gas which is necessary for the measurement will be continously and constantly with regard to time sucked in by a pump H_1 through the measuring cell whereas pump P_1, also driven by a synchronous motor, delivers the reaction solution in a constant quantity. Thereby, the constant quantity relation between measuring gas and reaction solution which is absolutely necessary for a correct measurement and an always continous reaction sequence within the measuring cell will be guaranteed.

To eliminate possible interfering substances such as hydrogen sulfide, hydrogen chloride and ammonia a heated filter cartridge is inserted in the measuring gas flow. The filter cartridge itself does not absorb sulfur dioxide.

5. Description of the Measuring Process within the Analyser

The measuring process can be taken from the scheme plan. The reaction solution will be sucked in by pump P_1 out of the storage vessel J and then pumped through the measuring cell G. Thereby, the reaction solution passes first the electrode measuring line G_1, the reaction tube G_4 and the electrode measuring line G_2. From there, the reaction solution, together with the measuring gas, will be led through line G_6 to the sepatator S and then sucked off by pump P_2.

The measuring gas will be sucked by pump H_1 through the heated selective filter into the measuring cell G where the measuring gas together with the reaction solution first pass the reaction tube G_4 and will then be led via the gas separator G_5 with glass ball and line G_6 to the separator S. From here, the remaining gas will be delivered to the outlet.

6. Devices for Function Control

In automatic measuring stations of which the analysers are controlled and regulated by a central station, the most important functions of the individual analysers

should be checked and recorded to the central station in order to increase the safety of the measuring results. A total control of the analyser function can be obtained by introducing a zero point gas and a test gas with a known quantity of the measuring gas component.

In the analyser ULTRAGAS-U3E the zero point gas and the test gas will be produced by construction elements integrated into the analyser and then be led into the measuring gas line via a valve combination E. The valve combination will be operated by a programme switch. During the measuring process only valve E_1 is open and pump H_1 sucks the measuring gas through the measuring cell. For the zero point control valve E_1 will be closed and valve E_2 opened. In this position pump H_1 sucks zero air through the measuring cell by means of the activated carbon purification train M_2.

For the control of the measured value indication, a test gas flow is produced in the analyser which will be sucked through the measuring cell with valve E_3 opened. For this purpose a permanent and constant flow of air will be led by pump H_2 via a purification train M_1 to the SO_2-test gas source G_{15} which is arranged in an oil bath. The quantity of SO_2 which diffuses through a diaphragm will be held constant by an exact adjustment of the oil bath temperature so that an exact SO_2-test gas will be obtained together with the carrier gas flow.

Moreover, the quantity of the sucked-in measuring gas can be controlled and signalised with device "A" and the flow of the reaction solution with device "B". The temperature of the measuring cell will be controlled by tracer "C".

An increased low pressure between gas measuring point and gas measuring pump H will be indicated by the diaphragm switch T_1. A further increase of the low pressure will open the by-pass valve V_1 and lead to a pressure compensation in the measuring gas line.

.../10

The dipped electrode T_2 controls the liquid level of the solution consumed in the separator S and in case of troubles it cuts off the analyser.

7.1 Composition of the ULTRAGAS-U3E (with and without casing)

In a compact 19"-casing the analyser ULTRAGAS-U3E contains the chemical-physical analyser part and the electrical measuring and control part. All construction elements of the analyser are clearly arranged on a mounting bracket. Alternatively, there is the possibility of a continous operation of the analyser for a time of 4 weeks resp. 2 months. The electrical function groups are arranged on 19"-plug-in units.

7.2 Composition of the ULTRAGAS-U3ES

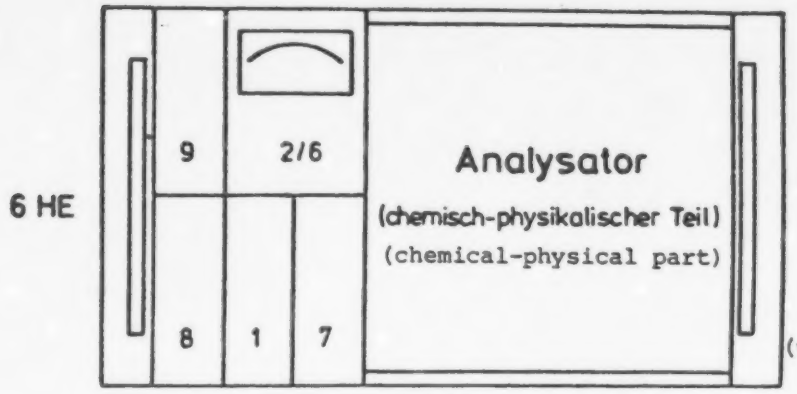
In the analyser ULTRAGAS-U3ES the chemical-physical analyser part and the electrical measuring and control part are arranged in two separate 19"-casings. The analyser part is identical with the U3E. But in the measuring and control part there are additional built-in possibilities for line-recorder, electronic integrator of the measured value and for a printer for measured value and time.

7.3 Composition of the ULTRAGAS-U3EK

The analyser U3EK contains the chemical-physical analyser part and the measuring and control part in a 19"-casing with a height of only 6 HE. The storage vessel with 11 l reaction solution enables a continous operation for a time of about 2 months.
The measuring and control part can be equipped with different plug-in units in accordance with the corresponding measuring task.

Aufbau des Analysators „Ultragas"

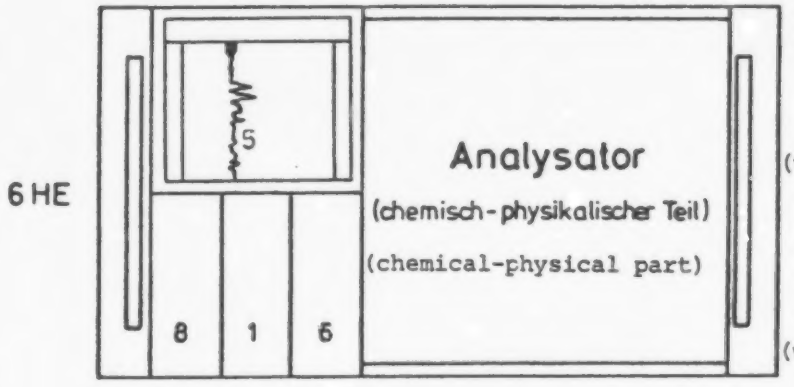
COMPOSITION OF ANALYSER "ULTRAGAS"



Typ U3EK

mit Anzeiger
with indicator

(mit und ohne Geh
(with and without casi



Typ U3EK

mit Linienschrei
(with line recorder)

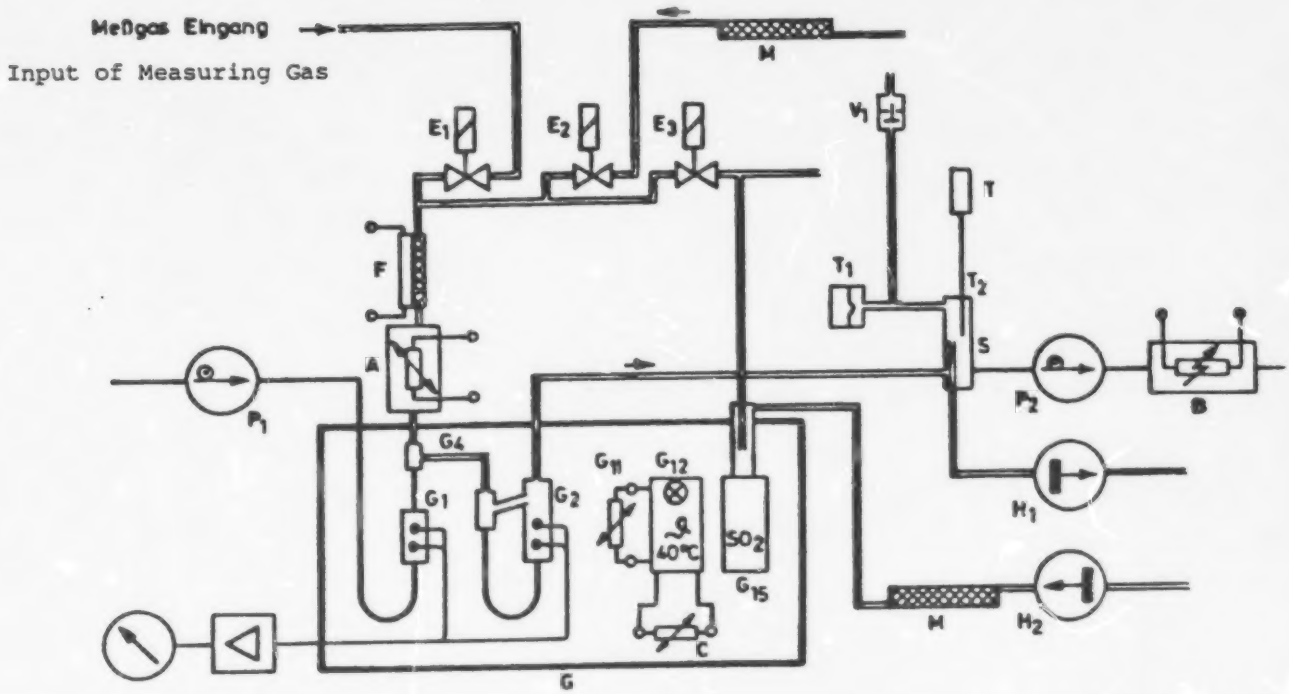
(mit und ohne Gehä
(with and without casi

1	Transmitter EMDU	output 0 (4)...20 mA
2/6	Indicator and Power Pack with Trouble Indication and Starting Switch	
5	Line Recorder 100 mm	
7	Automatic Changing-over of measuring range for 2 measuring ranges	
8	Automatic Change-over Device for 'Measuring', 'Zero Control' and 'Calibration Control' (23 h)	
	Type EZAN	
	Type EZRN (externally or by hand)	
9	Control of Gas- and Solution Delivery	ESGK
	and Temperature Control of Measuring Cell	ESTK
	and Temperature Control of Selective Filter	ESTF
-free-	for additional plug-in unit - within the carrier of the construction elements)	

FUNCTION SCHEME OF ANALYSER

Funktionsschema des Analysators

Ultragas U3E - SO_2



A	Control of Gas Delivery
B	Control of Solution Delivery
C	Temperature Control of Measuring Cell
E_1	Solenoid Valve "Measuring"
E_2	Solenoid Valve "Zero Control"
E_3	Solenoid Valve "Calibration Control"
F	Selective Filter with Heating
G	Measuring Cell
G_1	Electrode for new Reaction Solution
G_2	Electrode for consumed Reaction Solution
G_4	Reaction Tube
G_{11}	Heating
G_{12}	Heating Control
G_{15}	SO_2-Test Gas Source
H_1	Pump for Measuring Gas
H_2	Pump for Carrier Gas
M	Absorption Filter
P_1	Pump for Reaction Solution
P_2	Pump for consumed Solution
S	Separator
T	Safety Switch type MU
T_1	Diaphragm Switch for Low Pressure
T_2	Dipped Electrode, cuts the Analyser off if P_2 do not st
V_1	By-Pass Valve for Low Pressure

(A, B and C possible additional Equipment)

Blockschaltbild des Analysators

Ultragas U3E-SO_2

ULTRAGAS - U3EK - SO_2

Technical Data and Process Parameters* for
Measuring Range 0 - 200 µg/m³ SO_2

Measuring ranges		
Diminution I	:	0 - 200 µg/m³ SO_2 (75 ppb)
Diminution II	:	0 - 500 µg/m³ SO_2 (187.5)
Diminution III	:	0 - 2000 µg/m³ SO_2 (750)
Output of measured value	:	0 - 20 mA/4 - 20 mA (life ze
Load	:	0 - 250 Ω, alternatively 0 - 1000 Ω
Pressure of measuring gas	:	atmospheric
Delivery of measuring gas	:	about 6.6 l/h
Delivery of reaction solution	:	about 6 ml/h
Maintenace period	:	2 months
Energy supply	:	220 V ± 10 %, 50 Hz or Battery operation with inverter
Power consumption	:	about 100 W
Admissible temperature range at place of installation		
Stocking and transport	:	- 10 up to + 65° C without liquid
Operation	:	+ 2 up to 40° C
Uniform Federal minimum requirements fulfilled	:	5 up to 35° C
Humidity	:	relative humidity up to 95 % not condensing
Dimensions	:	H x W x D: 286 x 504 x 400 m
Weight	:	20 kp

* The indicated technical data are only for the description of the product and cannot be taken as guaranteed characteristics with regard to legal claims.
All rights of changes within the scope of technical developments are reserved.

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Fore-running time	:	60 min	
Dead time	:	40 sec	
Adjustment time (90 %-time incl. dead time)	:	100 sec	
Verification limit	:	1.5 µg/m³ SO_2	
Reproduceability	:		
at 30 µg/m³ SO_2	:	± 1.6 %	relative location deviation
at 50 µg/m³ SO_2	:	± 1.4 %	
at 100 µg/m³ SO_2	:	± 1.0 %	
at 200 µg/m³ SO_2	:	± 0.5 %	
Zero point drift/month	:	± 5 µg/m³ SO_2	
Sensibility drift/month	:	± 0.2 %	
Internal test gas generator drift/month	:	± 0.2 %	

Selectivity against ion-forming accompanying components of the measuring gas on application of the integrated, heated filter cartridge with deep dust filter:

Interfering component	Mass-concentration mg/m³	Deviation of SO_2-measured value* µg/m³
HCl	1.0	0.0
Cl_2	0.5	...
H_2S	1.0	0.0
NO	1.0	0.0
NO_2	0.3	1.5
	0.6	3.0
NH_3	1.0	0.0
PH_3	1.0	0.0
CO_2	900	0.0
	1800	+ 2.0
CH_4	100	0.0
H_2O	1000	- 1.0

*in each time determined at zero poi

APPENDIX B

SENSORS BASED ON CITY TECHNOLOGY ELECTROCHEMICAL CELLS

Conspec
44 Martin Ross Av.
Downsview, Ontario
M3J 2K8
Tel: (416) 661-0500
Contact: Robert Serbyn

J. Jones Autom. Ltd.
Daleside Rd.
Nottingham, England
NG2 4DH
Tel: (0602) 582111

Trolex*
Newby Rd.
Hazel Grove, Stockport
Cheshire
SK7 5DY
FAX: 061-483-5556

Armstrong Monit. Corp.
215 Colonnade Road South
Nepean, Ontario
K2E 7K3
Tel: (613) 225-9531

Sieger Limited**
31 Nuffield Estate
Poole, Dorset
U.K.
BH17 7RZ
Tel: (0202) 676161

Q.E.L.
18-i Enterprise Ave.
Nepean, Ontario
K2G 0A6
Tel: (613) 723-0960
Contact: Bill Goderre

* Distributed in Canada by: Minelec Ltd., 2610 Durwin Drive, Mississauga, Ontario, L5L 1J5

** Distributed in Canada by: Safety Supply, 8210 Trans Canada Hwy, St. Laurent, Quebec HS4 1S2, 514) 332-6105, Contact: Sophie Brouillard.

APPENDIX C

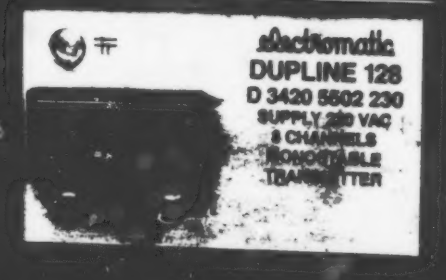
ELECTROMATIC, DUPLINE 2-WIRE COMMUNICATION SYSTEM

FOR MORE INFORMATION, CONTACT:

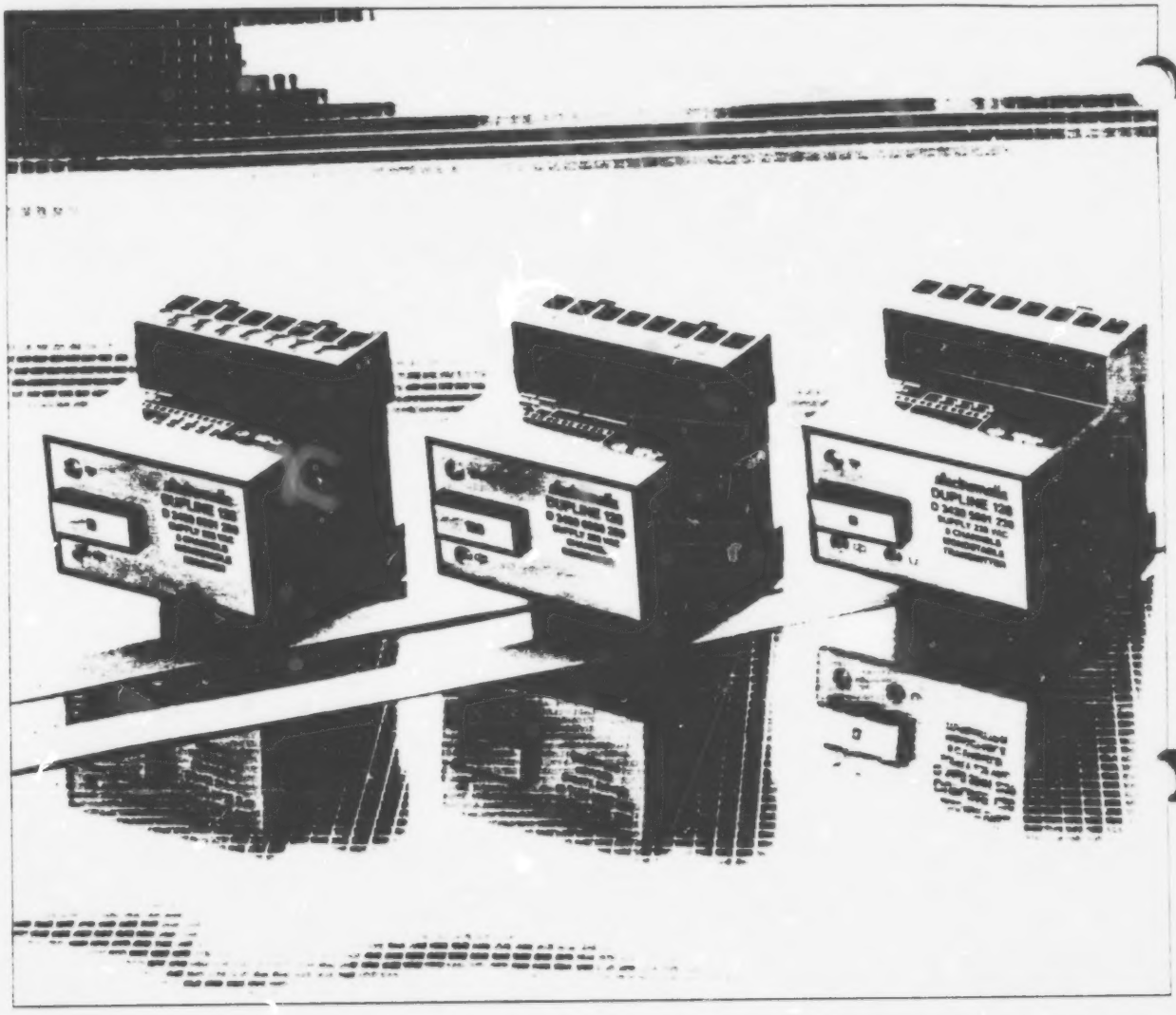
Roger Fortin
Electro-mag Ltd.
1670 Fleury East
Montreal, Quebec
H2C 1S8
Tel: (514) 383-7330

DUPLINE H·128

Two wire transmission system in DIN 43880 housing for monitoring and control



The Dupline system



It happens now and then within the field of electronics that a really epoch-making new product comes on the market. This has been the case with the radio, the tape recorder, the television, the pocket calculator and the computer.

It will also apply to ELECTRO-MATIC's new DUPLINE system, a 2-wire data transmission system consisting of modules for panel building-in and of modules for installation purposes. The DUPLINE system is made for today and for the future and will later be capable of forming part of a wide hybrid network, but meanwhile it can be used as independent monitoring and control units.

The DUPLINE system is based on 3 modules: a channel generator, a transmitter and a receiver — all working on a transmission line.

modules can emit and receive up to 128 signals at the same time and in all directions.

The general idea of the DUPLINE system is to place up to 128 transmitters, each having its own channel code, at random along a 2-wire cable of up to 10-15 km. Likewise at random are placed 128 receivers, each coded to work on one channel corresponding to the transmitters.

Function

The DUPLINE system is a 2-wire transmission system capable of transmitting 128 mutually independent signals simultaneously in any direction and over distances of up to 10-15 km and furthermore over long distances through our telephone modems.

Placement of channel generator

The transmission lines can be placed in a long straight line:

The channel generator can be connected to any point of the line, but in the case of extremely long lines (5-15 km) it is recommended to connect the channel generator in the middle of the line.

The transmission lines can also be placed in a circle:

In this case it is of no importance as far as function is concerned, where the channel generator is placed, but it would be a good

DUPLINE 128®

electromatic

Optolink

BELGIE
BELGIQUE

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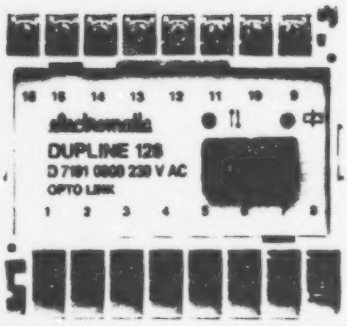
D 71910000



- **Dupline Optolink.**
- **Extremely high EMI immunity.**
- **Fast communication between Dupline networks.**
- **Supported by software driver.**
  Up to 50 m through plastic optical fiber cable.
  Up to 500 m through current loop.
- **Can be connected to RS 232 by interface type OLI V24.**
- **LED-indication: Dupline and supply on.**
- **AC power supply.**

DUPLINE® 128

SPECIFICATIONS

Power supply
24, 115 or 230 VAC ± 15%.
45-65 Hz.

Power consumption
4 VA.

Signals
Current loop:
Logic 1: 20 mA.
Logic 0: 0 mA (max. 12 V).
Input: SINK (R_{IN} 220 Ω)
Output: SOURCE (R_{OUT} 330 Ω/12V)
Common reference.

Current loop enable
Open: 12 VDC.
Closed: 20 mA.

Data speed
9600 BAUD.

Data format
1 start bit
8 data bits
1 stop bit.

Optical fiber cable (recommended values)
Basic data applying when the range is 50 m:
Material: Polymer.
Type: Stepindexed.
Max. loss: 220 dB/km (660 nm).
Typ. loss: 190 dB/km (660 nm).
Numerical aperture: 0.47.
Cable dimensions:
Diameter: 2.2 ± 0.1 mm.

Selection of device no.
The desired device no. is set by the 6-pin DIP switch at the rear of the housing. The DIP switch works as a binary-number system.

Connections
Current loop: Screw terminal.
Optical fiber: 2 sockets, type OVKD01 (Hirschmann).

LED-indication
Red LED for Dupline
Green LED for supply on

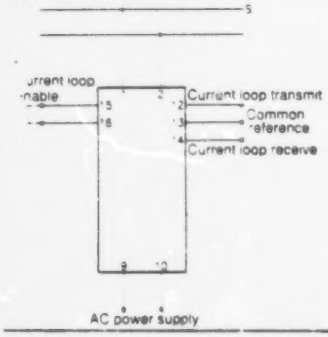
Housing
Material: ABS
Colour: Grey.
Weight: Approx. 500 g.

Ordering key

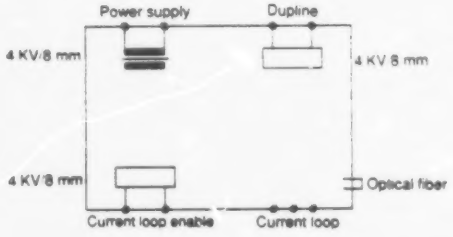
D 71910000 024:	24 VAC
D 71910000 115:	115 VAC
D 71910000 230:	230 VAC

Delivered with support software on a 5 1/4 inch 360 KB diskette and 20 cm single optical fiber cable and plugs.

WIRING DIAGRAM



ISOLATION



Accessories
Optical plug: OVKS 2.2 (Hirschmann).
Basic optical fiber cable:
Optical fiber cable, single: OFPS-xx.
Optical fiber cable, dual: OFPD-xx.
xx = length in metres.

MODE OF OPERATION

D 71910000 is a Dupline Optolink with 2 different transmission modes: through optical fiber or through current loop. The Optolink has 3 major applications:

1) Primarily it is an opto-isolated communication device intended for interconnection of 2 Dupline networks. The great advantage of this is that transmission becomes possible through areas with high EMI (electro-magnetic interference), because the optical transmission is totally immune to electric and magnetic noisefields. For this application 2 Optolinks must be used as interfaces between the two Dupline networks.

2) The Optolink can also be used as a direct interface to a computer if the computer has current loop input/output. If the computer only has RS 232 interface connections, the Optolink interface type OLI V24 can be used either with optical fiber input or current loop input. Simultaneous transmission on current loop and optical fiber outputs.

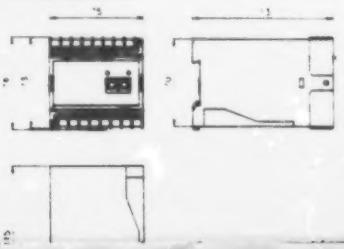
3) It is possible to make a host ring Local Area Network (LAN) by coupling up to 63 Optolinks in series. This gives up to 8064 Dupline channels (63 x 128), which can then be controlled by for example a PC or a computer.

Where net-to-net immunity is critical, optical fiber transmission is used (note that the max. distance between the Dupline Optolinks is 50 m). Where net-to-net EMI immunity is not critical, the current loop of the Optolink can be used in the above-mentioned applications instead of the optical fiber. The current loop ranges approx. 500 m (measured on a 0.25 mm^2 wire), and the Optolink must be enabled for current loop use (interconnection of terminals 15 and 16).

SPECTRAL BANDWIDTH

For optical fiber type OFPS-xx, OFPD-xx.

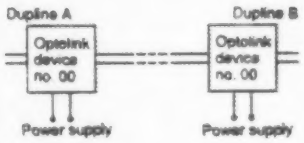
DIMENSIONS



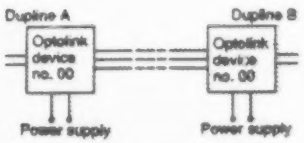
Applications

Optolink D 71910000 used as a Dupline-to-Dupline transmission system:

Through optical fiber
Range: up to 50 m



Through 3-wire current loop
Range: up to 500 m



Both Optolinks must be coded as device no 00. The length of the optical fiber can be up to 50 m. Optical fiber is highly advantageous in areas with high EMI. When using 3-wire current loop the maximum transmission range is increased to 500 m.

Absolute maximum Dupline-to-Dupline delay:

With 8 channels:	0.064 sec.
With 16 channels:	0.090 sec.
With 32 channels:	0.142 sec.
With 64 channels:	0.246 sec.
With 128 channels:	0.452 sec.

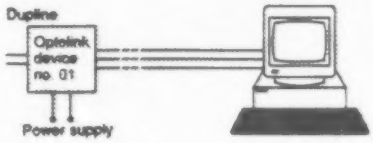
Delay arises because the Optolink must see all Dupline data twice before accepting the data (in order to ensure the highest possible accuracy of transmission). At least 1 scan will elapse before data will be transmitted on Dupline.

Max. delay needed to recover from broken communication lines is less or equal to max. Dupline-to-Dupline delay.

Increasing the range of Dupline
It is possible to connect several Optolinks. In this way an extremely wide Dupline range can be achieved. If for instance two Optolinks are connected, the Dupline range is doubled. Example: 2 x 10 km = 20 km. Just be aware of the time delay, which is 0.4 sec. per Dupline-to-Dupline transmission through Optolinks.

Optolink D 71910000 used as interface between Dupline and a personal computer:

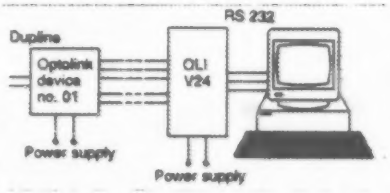
PC with 3-wire current loop I/O
Range: up to 500 m



The Optolink must be coded within the device no. range of 01 to 63.

The Optolink can be connected directly to a personal computer provided that it has a 3-wire current loop input/output.

PC with RS 232 I/O
Either 3-wire current loop or optical fiber
Range: up to 500 m



If the PC only has a RS 232 input/output, it is possible to use the OLI V24 interface together with either optical fiber I/O or 3-wire current loop I/O. You can freely choose the best solution for the application in question.

The communication is in accordance with the described Optolink telegram and gives simple and fast communication.

Optolink D 71910000 used in a host ring LAN for Dupline:

By using optical fiber cable and/or current loop as a ring LAN (Local Area Network)

When using Optolinks in a host ring LAN none of the devices may be given no. 00, which is for Dupline-to-Dupline communication only.

A total of up to 63 Optolinks can be connected in a host ring LAN giving the max. number of Dupline channels, i.e. 63 x 128 = 8064 channels).

The communication is in accordance with the Optolink telegram and enables reading from and writing to all devices. It is recommended to use the RS 232/Optolink interface type OLI V24 to separate the networks from the controlling computer.

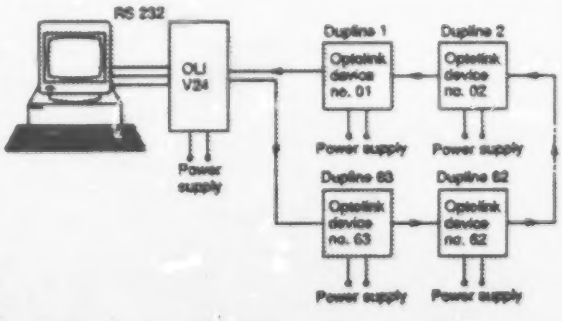
When a telegram is transmitted to any specified device, a reply will always be received reflecting the current state of the Dupline (status and number of databytes). Note that data previously written to that device will only appear in the reply telegram, if bit 5 in the status byte is set.

If you set bit 5 in the status byte, the reply will show all data: the current state of the Dupline as well as data previously written to that device.

If you want to read data from a device without changing the present state, you just send a telegram without data.

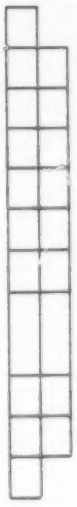
When you transmit data to a device, this data will be exactly reflected on the Dupline as it overwrites previous data.

Setting or resetting of one or more channels must be done from the controlling computer.



Optolink D 71910000 telegram transmission protocol

Start code always ASCII 73_H s		
Destination device	1 byte	2 characters
Number of databytes	1 byte	2 characters
Status	1 byte	2 characters
Source device	1 byte	2 characters
Data 1	1 byte	2 characters
Data 2	1 byte	2 characters
Data n	1 byte	2 characters
CRC 2's complementary sum	1 byte	2 characters
End code always ASCII 65_H e		



Start code: Denotes start of a new telegram. Any received start code initiate the reception of a new telegram.

Destination device: The no. of the unit with which you wish to communicate Optolinks must be given addresses within the range of 01 to 63. Optolinks must not have device no. 00 when used in a host ring LAN, as device no. 00 must only be used for Dupline-to-Dupline communication with two Optolinks, both having device no. 00.

Number of databytes: The number of 8-bit databytes, *not* the number of received data characters. Optolinks can only handle a maximum of 120 databytes, *or* else information will be lost.

Status: BIT 7 SET: Dupline error. Something has happened to the Dupline, e.g. the wire has broken.

BIT 6 SET: Receiver error. This bit checks the CRC and is set if it is wrong, thus indicating that the addressed Optolink has discharged the previously received telegram.

BIT 5 SET: Total status. Gives a complete status of all data, i.e. data set externally by transmitters and data set by Optolink.

Source device: The no. of the unit having transmitted the telegram. (The host PC is always device 00.)

Data 1 - n: 8-bit databytes, the max. number of databytes is 120.

CRC: This byte consists of the 2's complementary sum of destination device + number of databytes + status + source device + data 1 - n, all calculated in 8-bit binary.

End code: Denotes end of telegram.

Translation of 8-bit data into Optolink ASCII-HEX format

The 8-bit databyte (00-FF_H) 0-255 is translated into two nibbles which are then translated into two ASCII characters, as shown in the below table.

Every 8-bit databyte is transmitted nibble-wise, high nibble first followed by low nibble

Decimal	Hex	ASCII	OPTOLINK HEX
0	0	@	40
1	1	A	41
2	2	B	42
3	3	C	43
4	4	D	44
5	5	E	45
6	6	F	46
7	7	G	47
8	8	H	48
9	9	I	49
10	A	J	4A
11	B	K	4B
12	C	L	4C
13	D	M	4D
14	E	N	4E
15	F	O	4F
		s	73 (start code)
		e	65 (end code)

Example: The decimal value 127 is translated into Optolink ASCII/HEX values:

1) 127 is equal to $7F_H$ in the hexadecimal system.

2) According to the translation table $7F_H$ is translated into 7_H = G, F_H = O. $7F_H$ = GO. GO is then the Optolink ASCII value of the decimal value 127.

3) GO has the Optolink hexadecimal values G = 47_H, O = $4F_H$, GO = 47_H, $4F_H$.

Translation:

Normal		Optolink		
Decimal	HEX	ASCII	HEX	
127	$7F_H$	GO	47_H	$4F_H$

Dupline versus Optolink databyte
Channel group X:

Binary value for Optolink data	X1	X2	X3	X4	X5	X6	X7	X8
	2^7	2^6	2^5	2^4	2^3	2^2	2^1	2^0
	1. char.				2. char.			

Optolink D 71910000 telegram examples

Telegram for reading from a device

Example: You want to read from device no. $23_{10} = 17_H$:

Start code	HEX	DECIMAL	s		Start code is always s
Destination device	17_H	23_{10}	A	G	1 = A, 7 = G, see transm. prot.
Number of databytes	00		@	@	0 = @, 0 = @, see transm. prot.
Status	00		@	@	0 = @, 0 = @, see transm. prot.
Source device	00		@	@	0 = @, 0 = @, see transm. prot.
Sum total	17_H	23_{10}			
CRC: 256-sum total (256-23)=233_{10}=$E9_H$			N	I	E = N, 9 = I, see transm. prot.
End code			e		End code is always e

If you want to read from device no. 17_H from the computer, the following ASCII string must be transmitted:

sAG@@@@@@NIe

Optolink device no. 17_H replies with a telegram reflecting the current state of the Dupline (status and number of databytes). The reply telegram only contains data set on Dupline by transmitters, and not data set by Optolink.

If you want it to reflect both data set by transmitters and data set by Optolink, you set the status byte at 02_H, 00_H. According to the transmission protocol bit 5 in the status byte should be set.

Note that if device 17_H is used as the last unit to emit a serial signal to the computer, it will first transmit the inquiry telegram and then the reply telegram containing information from device 17_H. If, on the other hand, device 63 is used as the last unit, this unit will remove the inquiry telegram and transmit the reply telegram to the destination device. In this way the Optolink appears to the user to be a multi-drop network, in which the access time to any destination device is usually less than 100 ms. This is actually faster than the speed at which Dupline itself operates.

Telegram for writing to a device

Example: You want to write to device no. $33_{10} = 21_H$:

Start code	HEX	DECIMAL	s		Start code is always s
Destination device	21	33	B	A	2 = B, 1 = A, see transm. prot.
No. of data (group A)	01	01	@	A	0 = @, 1 = A, see transm. prot.
Status - ext. status read	00		@	@	0 = @, 0 = @, see transm. prot.
Source device (PC = 0)	00		@	@	0 = @, 0 = @, see transm. prot.
Data group A	E2	226	N	B	E = N, 2 = B, see transm. prot.
Sum total	104_H	260			
CRC: 100_H-04_H = FC_H			O	L	F = O, C = L, see transm. prot.
End code			e		End code is always e

Channels A1, A2, A3, A7 set.
Channels A4, A5, A6, A8 cleared.
Channel groups B - P not used.
External status only.

A1	A2	A3	A4	A5	A6	A7	/
1	1	1	0	0	0	1	0
E_H				2_H			

If you want to write to device number 21_H from the computer, the following ASCII string must be transmitted:

sBA@A@@@@NBOLe

Example of telegram (printed out)

Inquiry telegram for device 18 (12 hex), reply with all required data.

sAR@@B@@@LNe

Data telegram from device 18 (12 hex), 16 channel groups, reply with total status, as required during request.

group A = 11111111
group B = 11101110
group C = 11011101
group D = 11001100
group E = 10111011
group F = 10101010
group G = 10011001
group H = 10001000
group I = 01110111
group J = 01100110
group K = 01010101
group L = 01000100
group M = 00110011
group N = 00100010
group O = 00010001
group P = 00000000

sAB@@B@@@LNes@@A@B@ABOONNMMLLKKJJIIHHGGFFEEDDCCBBAA@@LFe

ELECTROMATIC
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The channel generator, programmable by means of a code module, can produce 8, 16, 32, 64 or 128 channels as required.

At the same time it works as power supply for transmitters which have no power supply of their own.

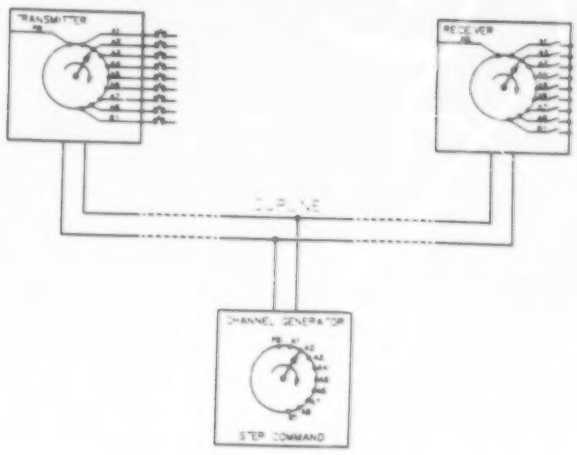
The channels produced by the channel generator can each signify a digital signal: »0« or »1«. Analogue input-signals can be transmitted using transmitters containing analogue to digital converters.

The transmitter is programmed by a code module to transmit on one or more channels. If the transmitter input is activated, the transmitter will activate the receiver through the channel generator and change the channel status. A change in channel status will be registered by all receivers coded for this channel along the transmission lines.

The transmission lines can be any two-wire twisted cable selected only by resistance and capacitance parameters. Such cables could be telephone wires, ordinary installation cable, shielded if required.

It is possible to switch to another kind of cable throughout the installation. As an example you can use an ordinary telephone cable over a distance and then switch to a shielded cable.

Simplified Dupline:



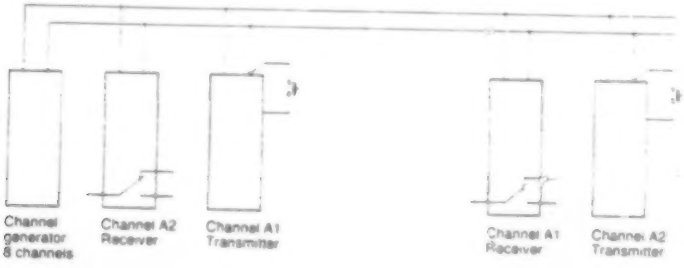
If for instance transmitter contact A2 is activated, the receiver contact having the same number (A2) will be activated when it becomes its turn during the sequence.

The receiver contact will automatically remain activated for one sequence and in the next sequence will then either release or remain activated depending on the position of the transmitter contact.

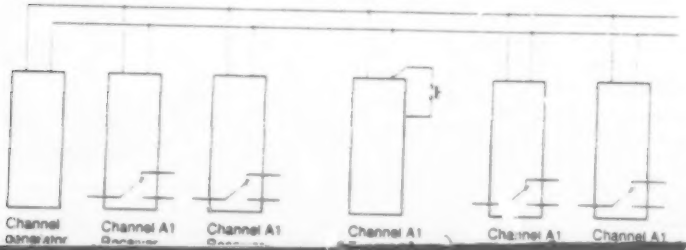
This shows that all 128 contact functions (1 sequence) can be transmitted simultaneously on the Dupline.

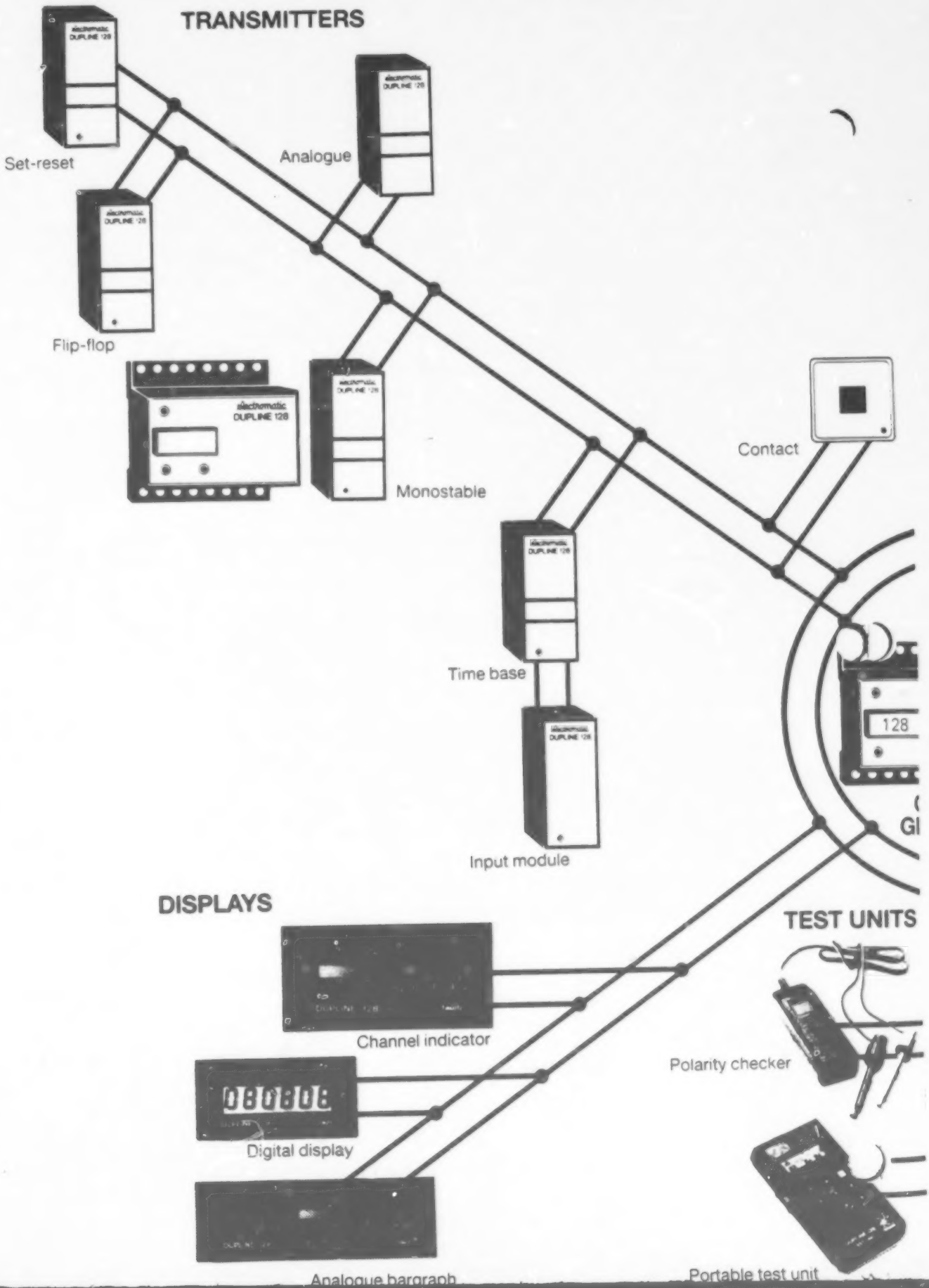
The transmission system in its simplest form:

You can also re-transmit signals:

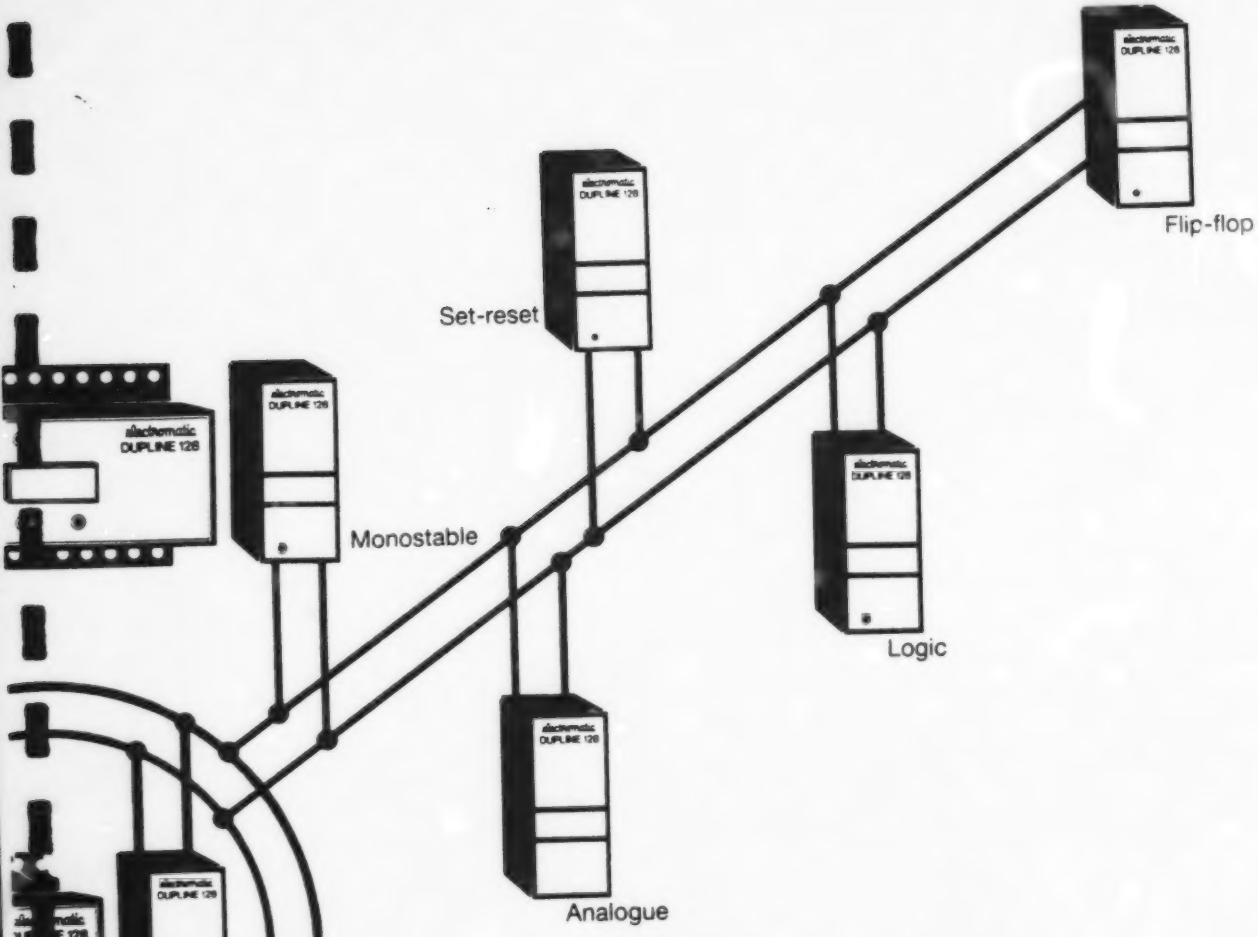


One transmitter can control several receivers:




TRANSMITTERS
Set-reset
Analogue
Flip-flop
Monostable
Contact
Time base
Input module
DISPLAYS
TEST UNITS
Channel indicator
Polarity checker
Digital display
Analogue bargraph
Portable test unit

RECEIVERS

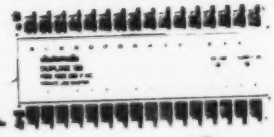


ANNEL
ATOR

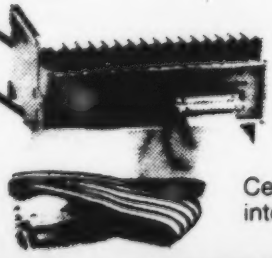
CLOCKS

Master clock

MODEMS AND INTERFACES



APL modem



Centronic
interface

RS 232

Production programme

Transmitters

Function	Channels	No. of in/outputs	Description	Contact/NPN	5 - 265 VAC/DC	NPN	PNP	MOS	TRIAC	SPDT	24 VAC	115 - 120 VAC	220 - 230 VAC	10 - 30 VDC	12 VDC	Wiring diagram	Type no.
Monostable	1	1	Contact/NPN/PNP 8 VDC - 3 mA	X							024	115	230	800		A	D 34201101
Monostable	2	2	Contact/NPN 8 VDC - 3 mA	X							024	115	230	800		B	D 34202201
Monostable	4	4	Contact/NPN 8 VDC - 3 mA	X							024	115	230	800		C	D 34204401
Monostable	4	4	Voltage 5 - 265 VAC/DC. Current limiter		X						024	115	230	800		D	D 34204402
Monostable	8	8	Contact/NPN 8 VDC - 3 mA	X							024	115	230	800		E	D 34205501
Monostable	8	8	Voltage 5 - 265 VAC/DC. Current limiter		X						024	115	230	800		F	D 34205502
- with delay on transmit	1		1 built-in contact														D 8110 1100
- with delay on transmit	2		2 built-in contacts														D 8110 2200
Flip-flop	1		1 built-in contact														D 8112 1100
- with LED - transmit	1		1 built-in contact														D 8112 1100-1
- with LED - non transmit	1		1 built-in contact														D 8112 1100-2
2 × flip-flop	2		2 built-in contacts														D 8112 2200
Monostable	1		Magnet activation														D 8910 1100
Monostable	1		Magnet activation (with thread)														D 8910 1100-G
Monostable	1		Inductive														D 8910 1105
Monostable (matrix 8×8)	64	64	Separately supplied, 64 contacts	X							024	120	220				FFX 1861

Receivers*

Function	Channels	No. of in/outputs	Description	Contact/NPN	5 - 265 VAC/DC	NPN	PNP	MOS	TRIAC	SPDT	24 VAC	115 - 120 VAC	220 - 230 VAC	10 - 30 VDC	12 VDC	Wiring diagram	Type no.
Monostable	1	1	2.2 A/60 VDC NPN/PNP				X				024	115	230	800		G	D 34301112
Monostable	1	1	2 A/250 VAC					X			024	115	230			H	D 34301132
Monostable	1	1	10 A/250 VAC						X		024	115	230	800		J	D 34301149
Monostable	2	2	1.6 A/60 VDC			X					024	115	230	800		K	D 34302211
Monostable	2	2	1.6 A/60 VDC				X				024	115	230	800		L	D 34302221
Monostable	2	2	1.6 A/250 VAC					X			024	115	230			M	D 34302231
Monostable	2	2	10 A/250 VAC						X		024	115	230	824		N	D 34302249
Monostable	4	4	0.7 A/60 VDC			X					024	115	230	800		O	D 34304411
Monostable	4	4	0.7 A/60 VDC				X				024	115	230	800		P	D 34304421
Monostable	4	4	0.6 A/250 VAC					X			024	115	230			Q	D 34304431
Monostable	8	8	0.7 A/60 VDC			X					024	115	230	800		R	D 34305511
Monostable	8	8	0.7 A/60 VDC				X				024	115	230	800		S	D 34305521
Monostable	8	8	0.6 A/250 VAC					X			024	115	230			T	D 34305531
Monostable	64	8X8	Matrix output								024	120	220				FAX 1861

Displays

Function	Channels	No. of in/outputs	Description	Contact/NPN	5 - 265 VAC/DC	NPN	PNP	MOS	TRIAC	SPDT	24 VAC	115 - 120 VAC	220 - 230 VAC	•	••	12 VDC	Wiring diagram	LED	LCD
Channel indicator	4		4 segments - parallel transmission								024	120	220	700	712			FK3C 3404	FL3C 3404
Channel indicator	8		8 segments - parallel transmission								024	120	220	700	712			FK3C 3508	FL3C 3508
Channel indicator	16		16 segments - parallel transmission								024	120	220	700	712			FK3C 3616	FL3C 3616
Channel indicator	32		32 segments - parallel transmission								024	120	220	700	712			FK4C 3732	FL4C 3732
Analog bargraph	2		4 segments - binary transmission								024	120	220	700	712			FK3C 5204	FL3C 5204
Analog bargraph	4		8 segments - binary transmission								024	120	220	700	712			FK3C 5408	FL3C 5408
Analog bargraph	4		16 segments - binary transmission								024	120	220	700	712			FK3C 5416	FL3C 5416
Analog bargraph	8		32 segments - binary transmission								024	120	220	700	712			FK4C 5532	FL4C 5532
Digital display	8		0-99 7 segments parallel BCD transm.								024	120	220	700	712			FK3C 7520	FL3C 7520
Digital display	16		0-9999 7 segments parallel BCD transm.								024	120	220	700	712			FK3C 7640	FL3C 7640
Digital display	32		0-999999 7 segments parallel BCD transm.								024	120	220	700	712			FK3C 7760	FL3C 7760

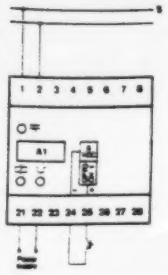
Miscellaneous

Function	Channels	No. of in/outputs	Description	Contact/NPN	5 - 265 VAC/DC	NPN	PNP	MOS	TRIAC	SPDT	24 VAC	115 - 120 VAC	220 - 230 VAC	10 - 30 VDC	12 VDC	Wiring diagram	Type no.
Channel generator**											024	115	230	824		U	D 34900000
Thermostat	1		Built-in temp. sensor - adjust.: 18 - 24°C														D 8910 1110
Pyro detector	1		Passive infrared detector														D 8910 1120
Modem - private line	128		Master unit								024	120	220				FMX 1902
Modem - private line	128		Slave unit								024	120	220				FMX 1903
Interface - RS 232	128		Serial computer interface								024	120	220				FMX 1911
Interface - Centronic	128		Printer interface								024	120	220				FMX 1912
Master clock	16		4-digit, 24 hours function								024	120	220				FW3C 1610
Slave display	16		4-digit, 64 mm LED, 24 hours function								024	120	220				FKX 7640
Polarity checker			Test unit for the Dupline system														FTU 1
Portable test unit	128		Monitoring- and transmitting mode														FTU 8
Micro prg.able controller	64		32/32 in/outputs								024	120	220				PLCF 223232
Micro prg.able controller	64		32/32 in/outputs								024	120	220				PLCF 323232
Code module	8		Channel group A														FMK 8
Code module	16		Channel groups A-B														FMK 16
Code module	16		Channel groups A-B, 2-cycle delay														FMK 16-2D
Code module	16		Channel groups A-B, 3-cycle delay														FMK 16-3D
Code module	32		Channel groups A-D														FMK 32
Code module	32		Channel groups A-D, 2-cycle delay														FMK 32-2D
Code module	32		Channel groups A-D, 3-cycle delay														FMK 32-3D
Code module	64		Channel groups A-H														FMK 64
Code module	64		Channel groups A-H, 2-cycle delay														FMK 64-2D
Code module	64		Channel groups A-H, 3-cycle delay														FMK 64-3D
Code module	128		Channel groups A-P														FMK 128
Code module	128		Channel groups A-P, 2-cycle delay														FMK 128-2D

* The stated current output data apply when only one output is activated.

• LCD only.
•• LED only.

Wiring diagrams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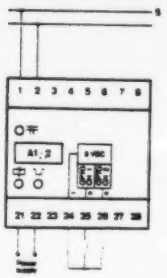
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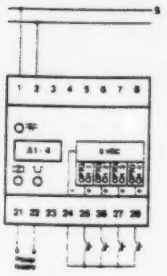
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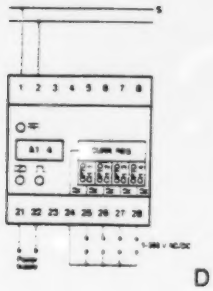
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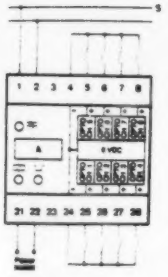
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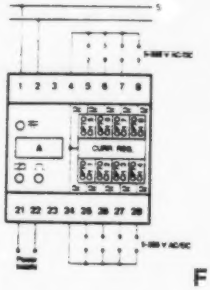
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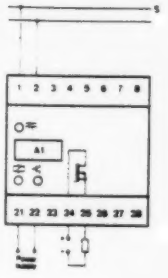
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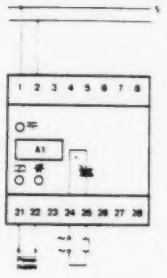
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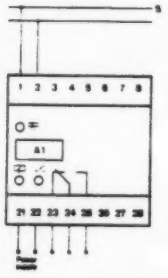
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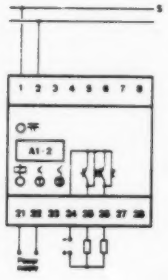
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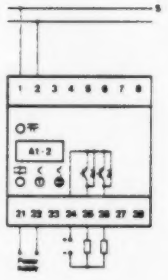
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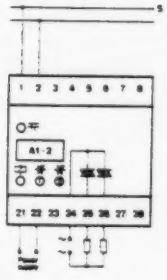
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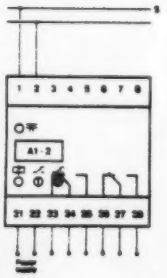
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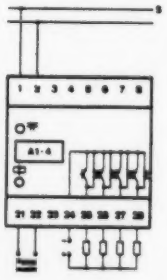
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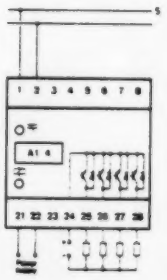
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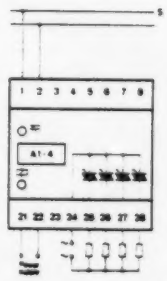
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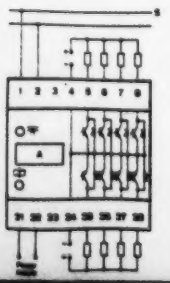
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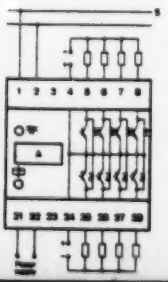
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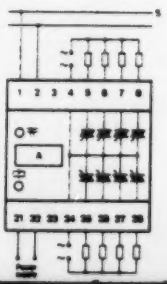
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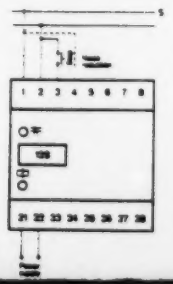


Common technical data and dimensions

Power supply
AC power supply:
230 = 195 to 265 VAC (continuously).
220 = 198 to 242 VAC.
120 = 108 to 132 VAC.
115 = 95 to 135 VAC (continuously).
024 = 20 to 28 VAC (continuously).
Apply to systems in D 34 housing.
024 = 21.5 to 26.5 VAC.
45 - 65 Hz.

DC power supply:
824 = 15 to 30 VDC.
800 = 10 to 30 VDC.
712 = 10.8 to 13.2 VDC.
700 = 10 to 30 VDC.

Isolation
D 34xx
4 KV/8 mm at AC supply.
Reduced at DC supply — see data sheet.

FKxC — FLxC
2 KV/4 mm at AC supply.

FMX
4 KV/8 mm at AC supply.

Power consumption
Specified under each type.
Note that the current consumption per system in the Dupline network is max. 400 µA, which means that max. 150 systems can be used in one Dupline network.

Ambient temperature
Operation: −20 to +50°C (− 4 to +122°F).
Storage: −50 to +85°C (−58 to +185°F).

Supply interruptions
No Dupline system reacts to supply interruptions of less than 2 cycles.

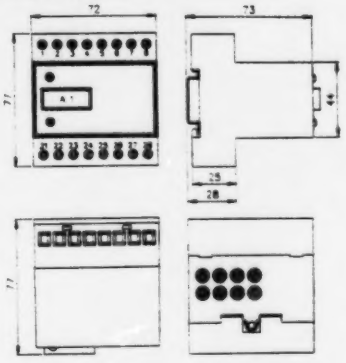
Voltage stabilisation
All Dupline systems have built-in voltage stabilisation.

Transient protection
> 3 KV.

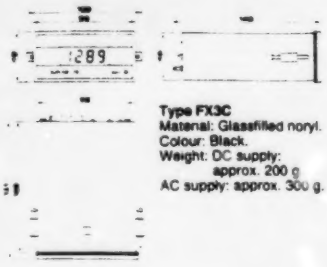
Duration of connection
100%.

NOTE:
All stated data apply at an ambient temperature of 25°C (77°F).

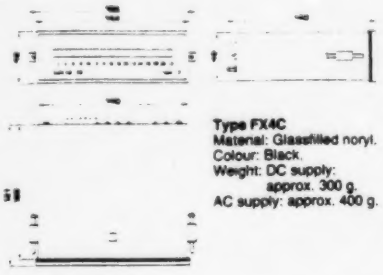
Type D34
Material: Noryl SE 1.
Colour: Black.
Weight: Approx. 250 g.



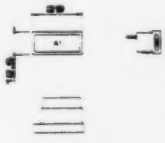
In the triac version the fuses are at the rear of the housing.



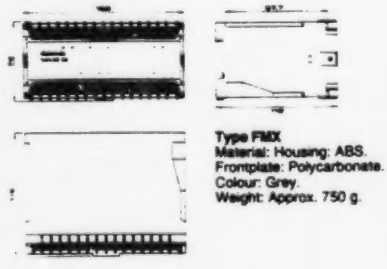
Type FX3C
Material: Glassfilled noryl.
Colour: Black.
Weight: DC supply: approx. 200 g
AC supply: approx. 300 g.



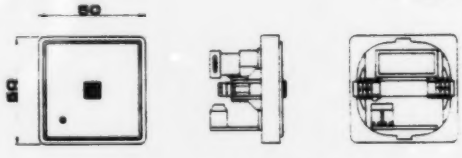
Type FX4C
Material: Glassfilled noryl.
Colour: Black.
Weight: DC supply: approx. 300 g.
AC supply: approx. 400 g.



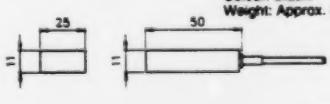
Type FMK
Material: Noryl SE 1.
Colour: Black.
Weight: Approx. 5 g.



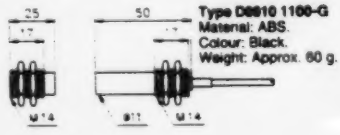
Type FMX
Material: Housing: ABS.
Frontplate: Polycarbonate.
Colour: Grey.
Weight: Approx. 750 g.



Type D01
Material: ABS.
Colour: Grey.
Weight: Approx. 60 g.



Type D0910 1100
Material: ABS.
Colour: Black.
Weight: Approx. 40 g.



Type D0910 1100-G
Material: ABS.
Colour: Black.
Weight: Approx. 60 g.

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ELECTROMATIC

APPENDIX D

BURN-CUT AND DRIFT ROUND DESIGN AT BMS-M

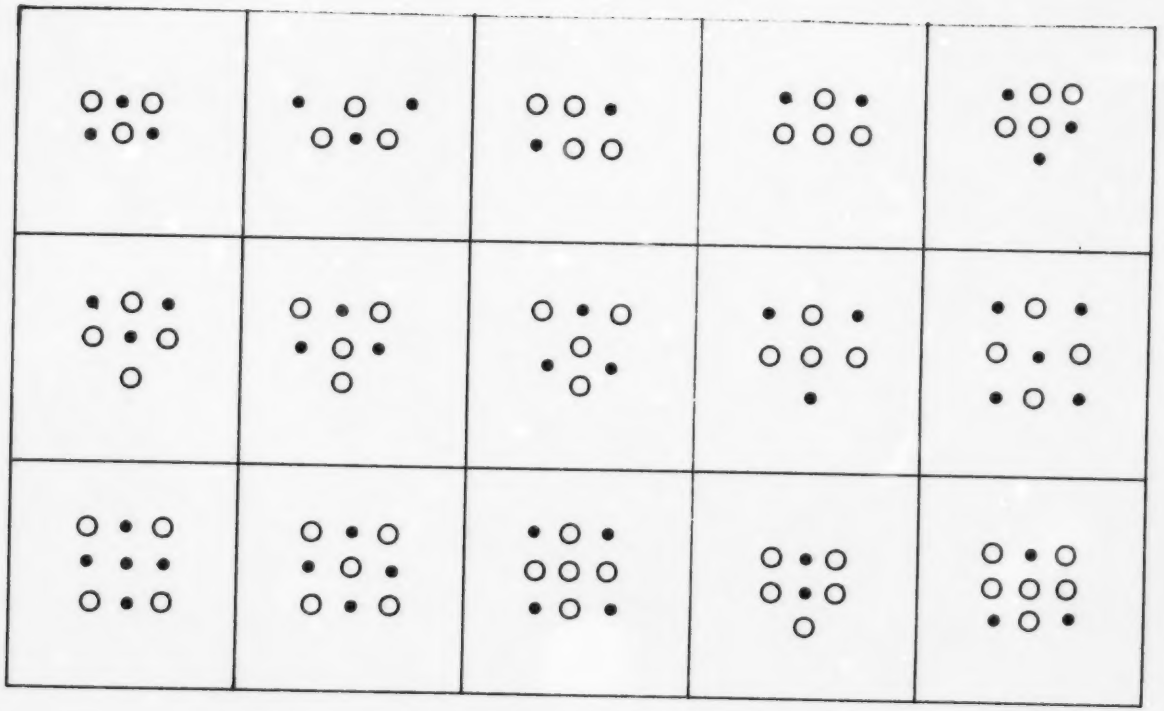


Figure D-1 Different Cut Designs Used at BMS-M

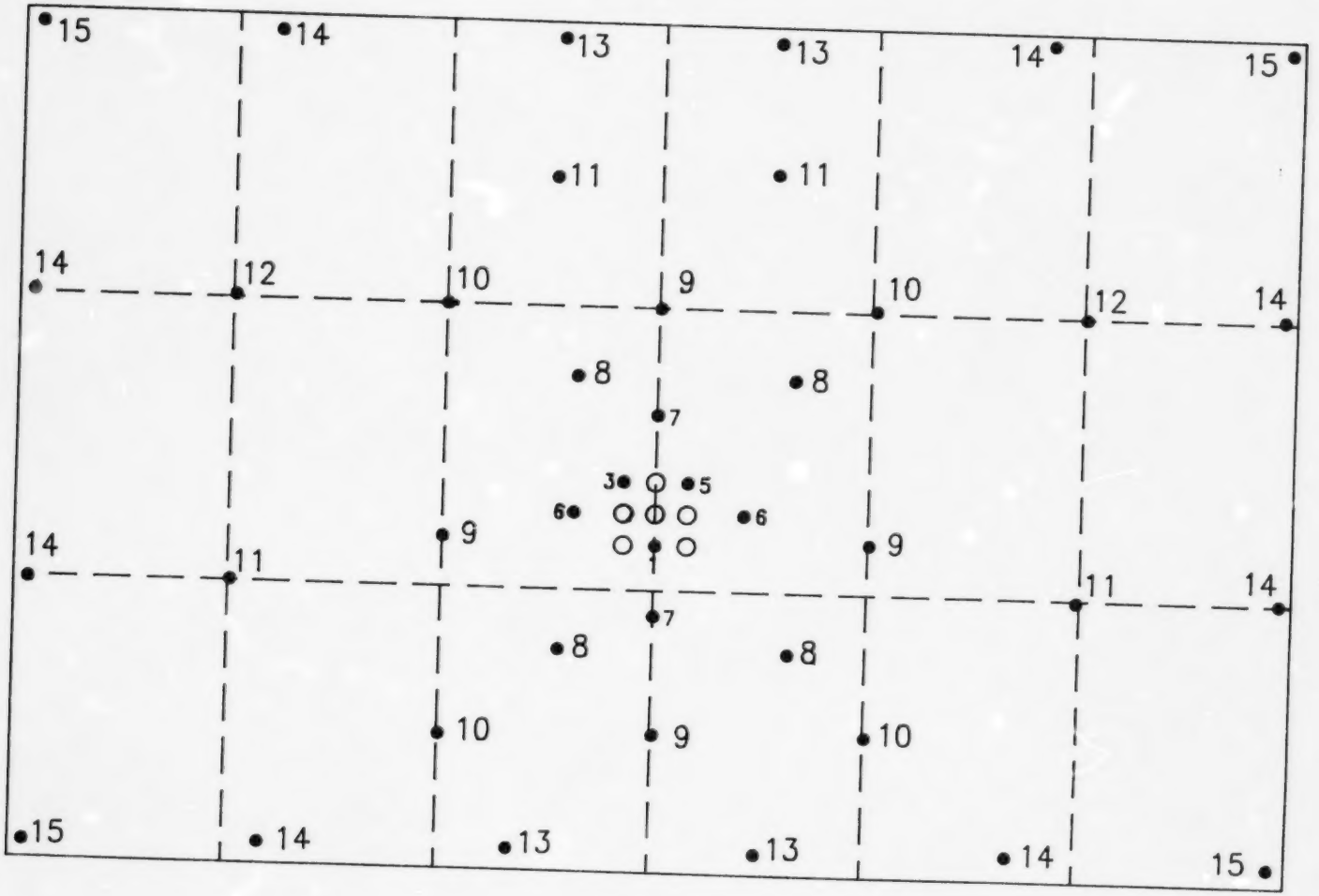


Figure D-2 BMS-M 48-Hole Pattern

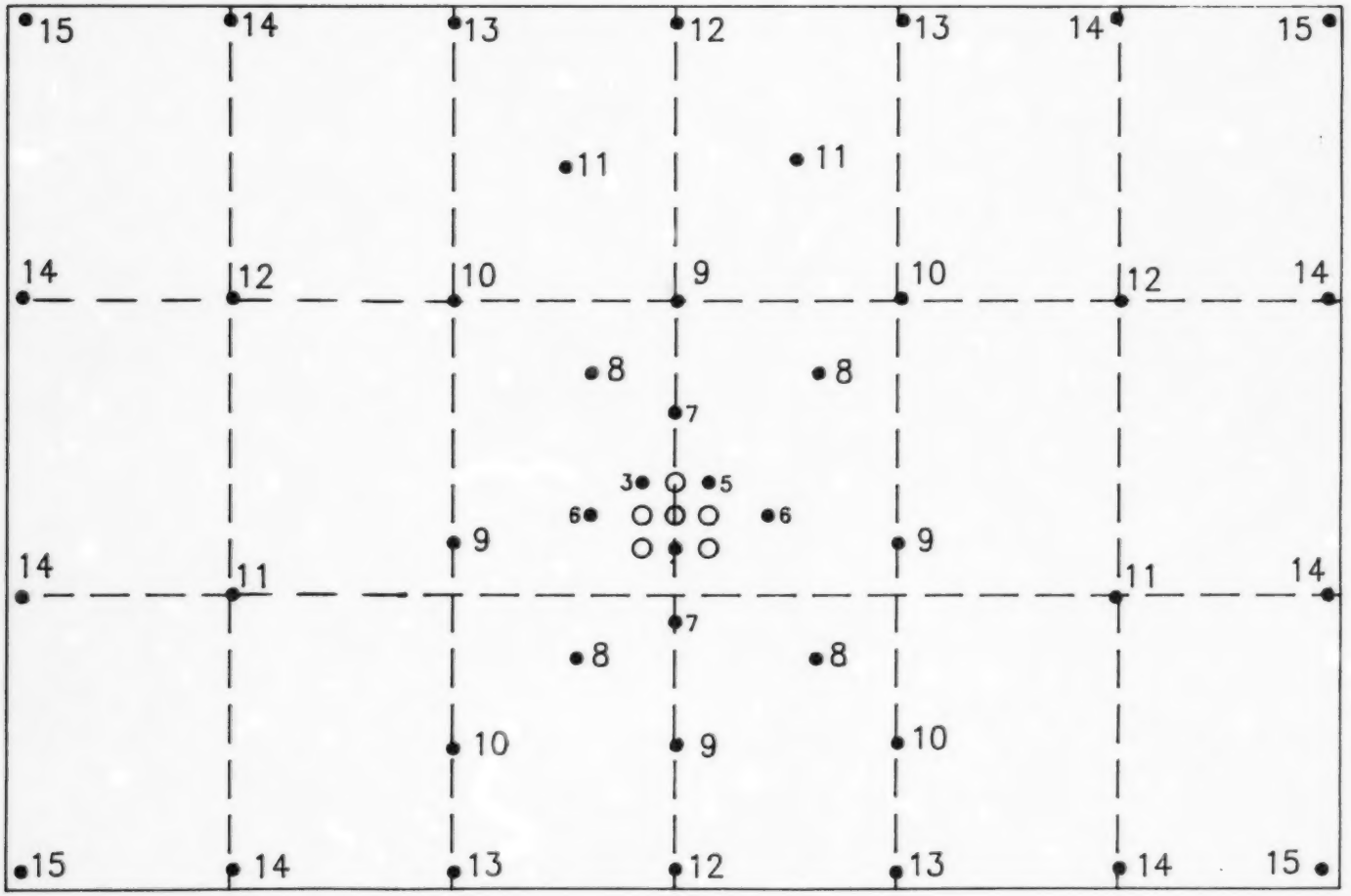


Figure D-3 BMS-M 50-Hole Pattern

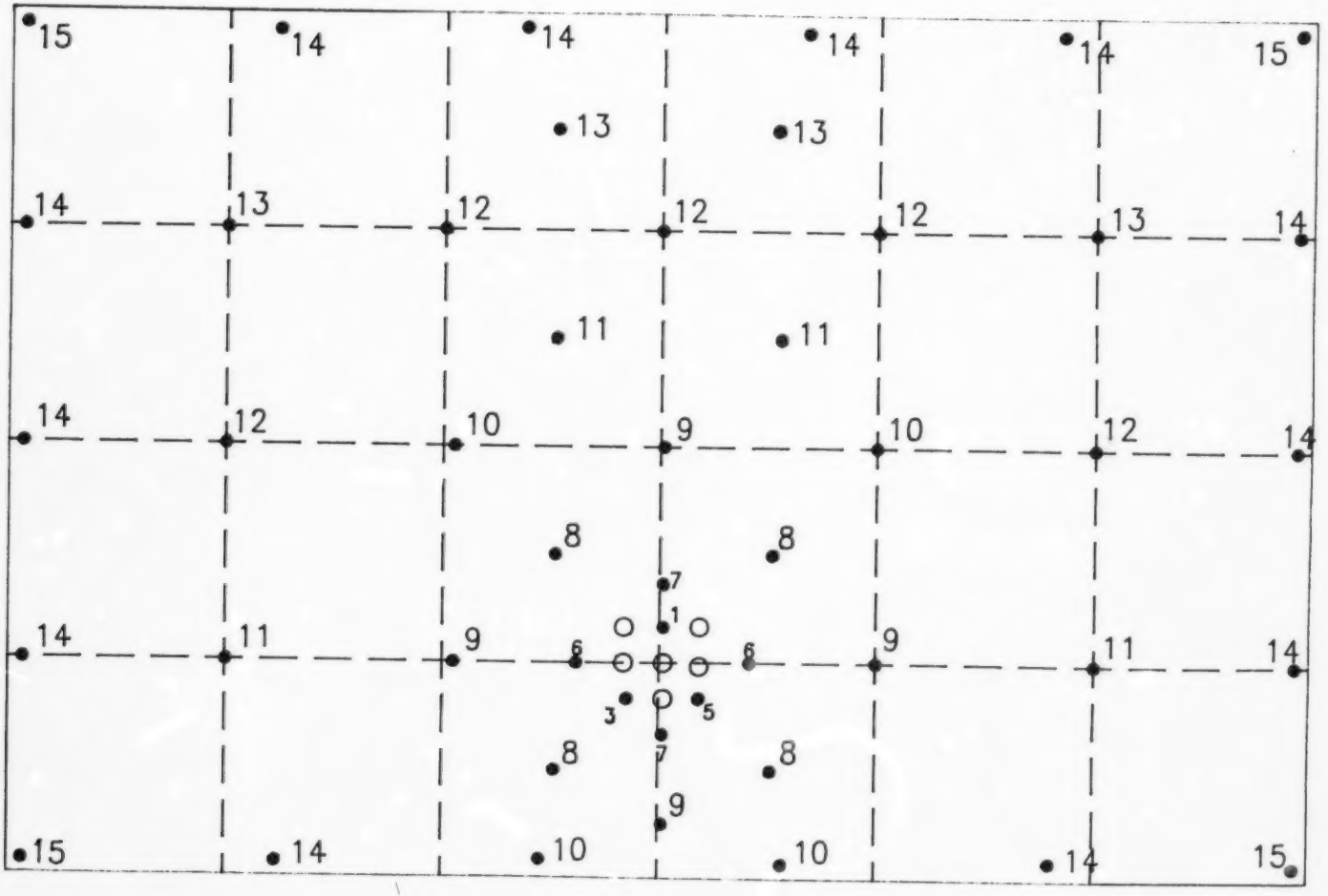


Figure D-4 BMS-M 54-Hole Pattern

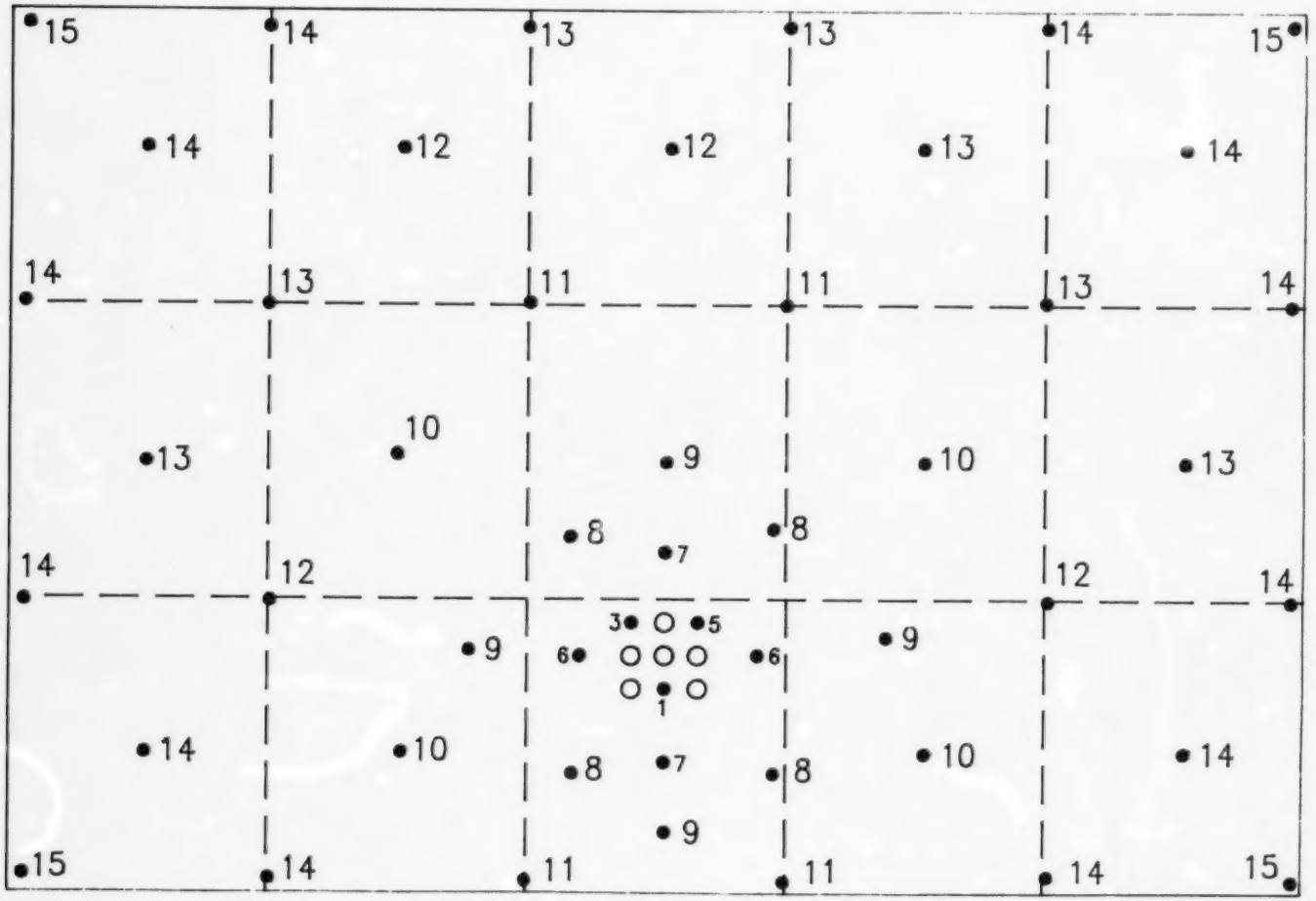


Figure D-5 BMS-M 56-Hole Pattern

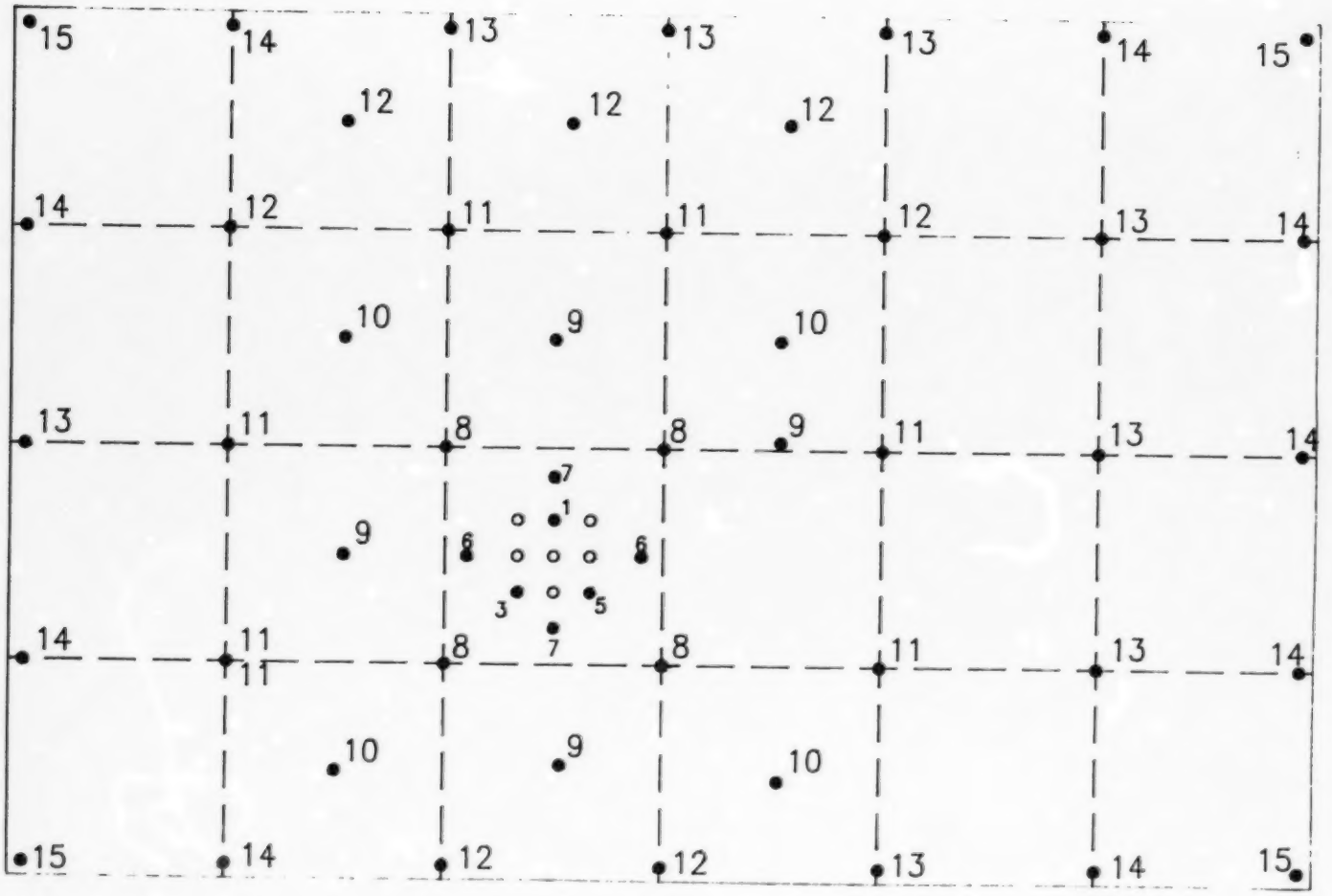


Figure D-6 58-Hole Pattern

APPENDIX E

FIELD INSTRUMENTATION

A) USBM Dust Probes

The USBM dust probe principle of operation is based on the principle of attenuation, or scattering, of a beam of radiation through a dust cloud. The basic component of the probe is a U-shaped section with a path length for light transmission across the open end of the U. Incorporated into the section are a light-emitting diode (LED) light source and a photo detector; both are solid-state devices. The gallium arsenide LED used in these probes emits near-infrared radiation with a wavelength of 0.95 m and a bandwidth of about 0.05 m. The response time of the silicon photodiode is typically 1 sec.

When installed underground, the dust cloud passes through the U-section and attenuates the light. For a flowing system (such as blasting), the plane of the U-section is placed perpendicular to the flow to minimize disturbance of theflow field. The support rod at the base of the U-section is bolted to rock bolts on the back of the tunnel.

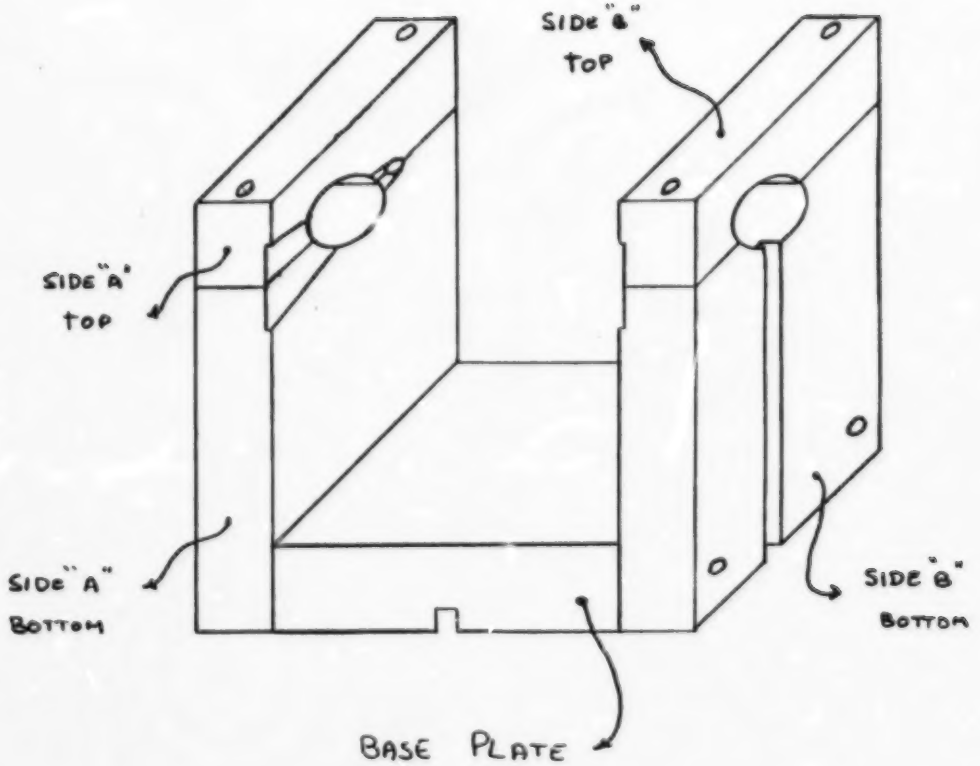
For this type of dust probe, the lenses or windows are exposed to the dust. The light can therefore be attenuated by both the airborne dust cloud and by the dust coating on the lenses left by the high velocity dust clouds. To minimize the dust coating, thin jets of air were used to keep the windows free from dust coating. The air was fed from compressed air underground through internal passageways in the probe to a channeled cover plate; the air then exits from the channel through a 0.5 by 5 mm split opening to sweep across each window.

The probes were not calibrated for the type of dust found in the test site at BMS-M. The output data would only be used for relative comparison.

The following six diagrams represent various scaled views of the dust probe.

'3 D' OF DUST PROBE.

design Claude
drawing Claude.

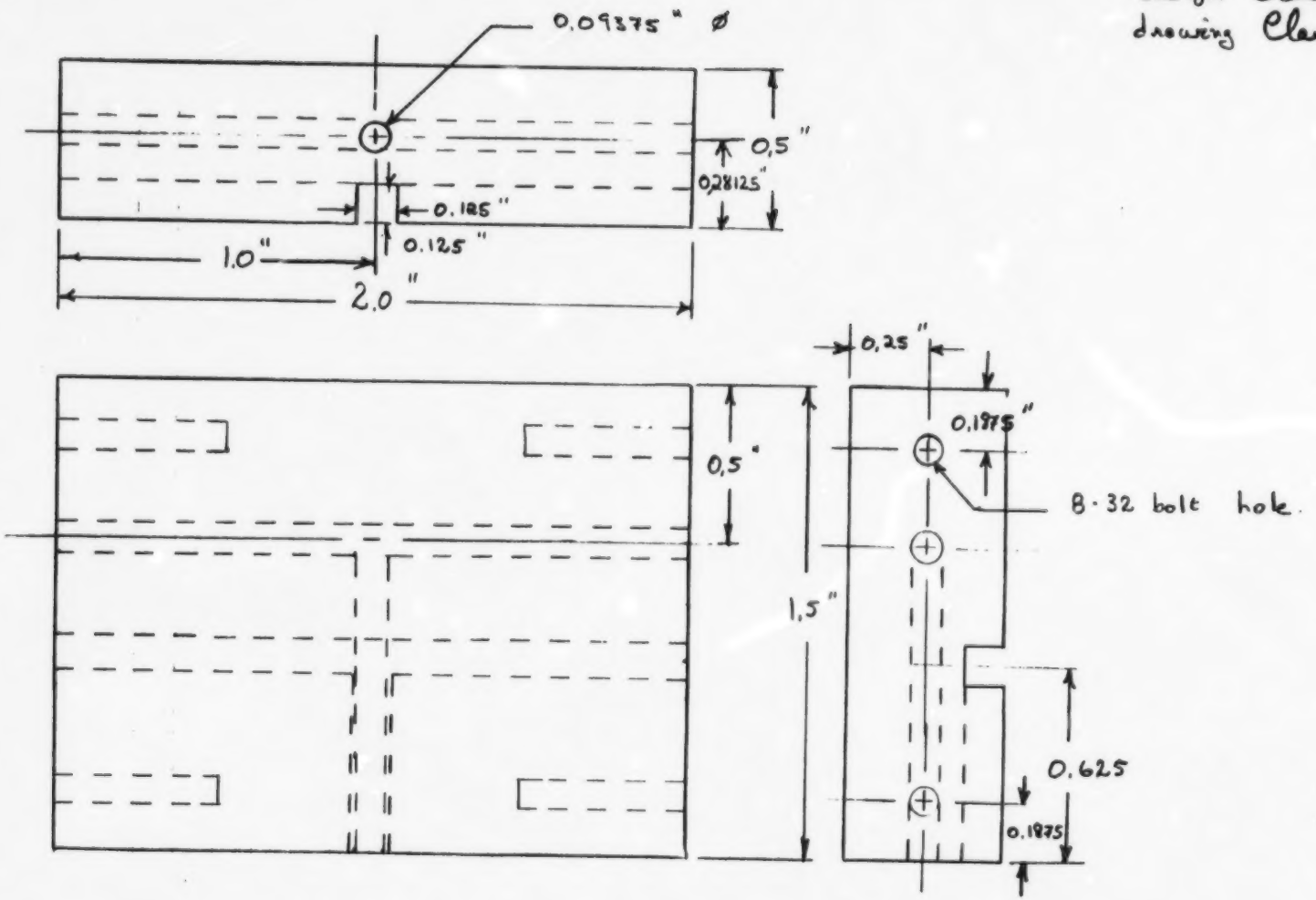


Claude

BASE PLATE.

design Claude

drawing Claude.

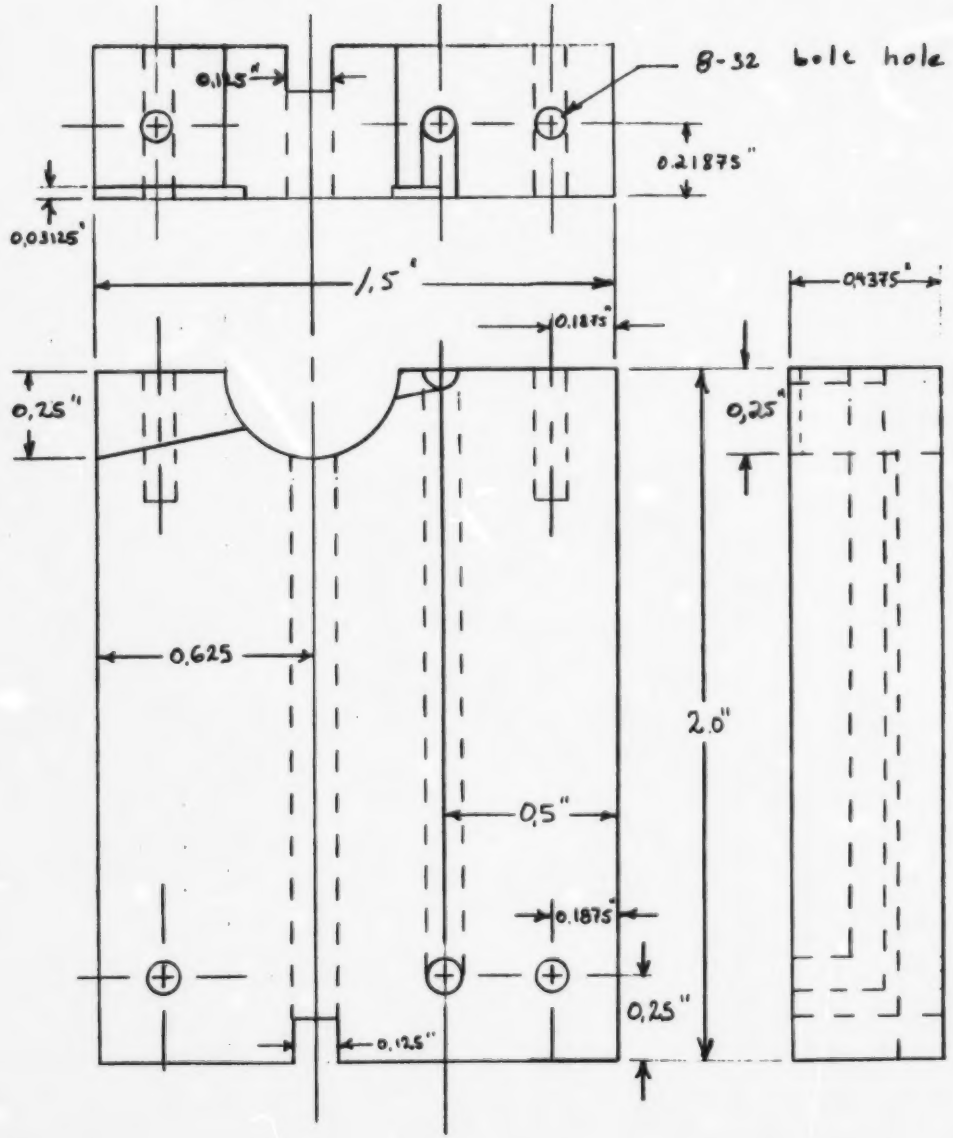


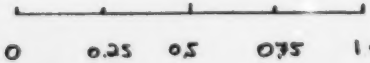
0 0,25 0,5 0.75 1,0 INCH

Claude

15 juin 88

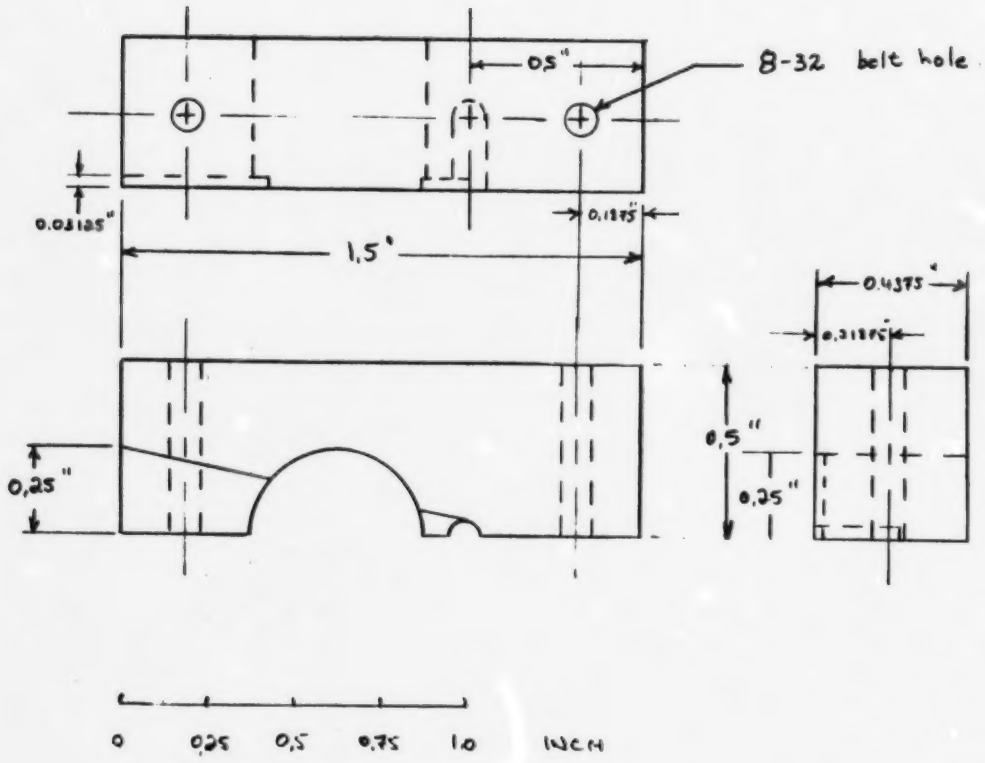
SIDE "A" Bottom
design Claude
drawing Claude



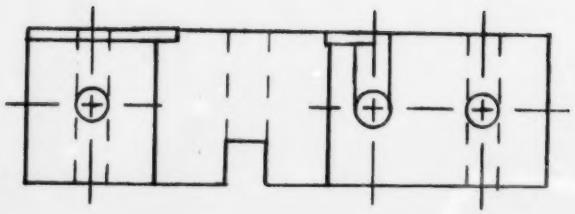


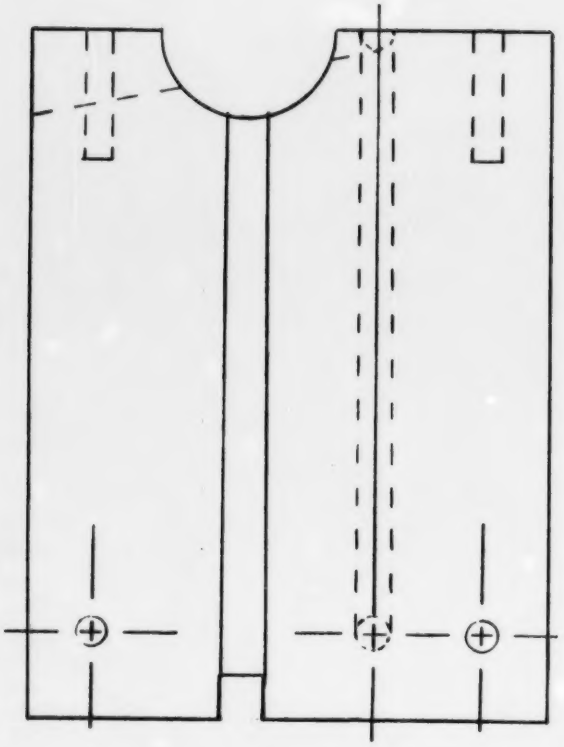
Claude
16 juin 88 (2)

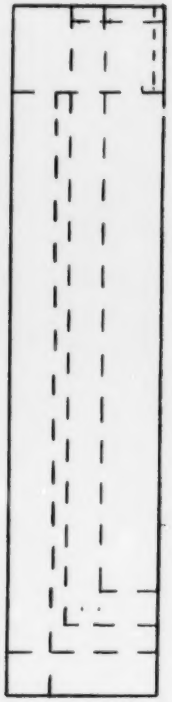
SIDE "A" top
design Claude
drawing Claude



Claude







0 0.25 0.5 0.75 1.0 INCH.

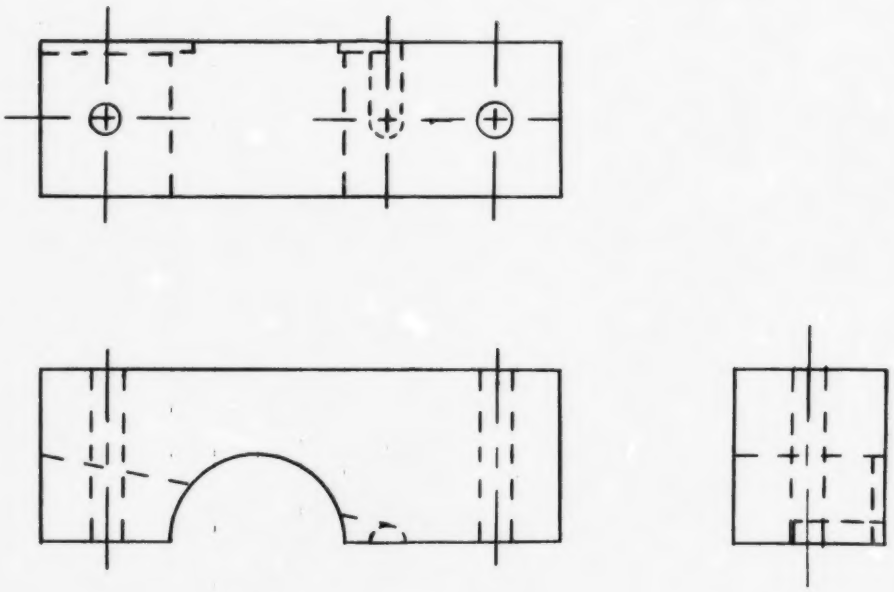
SIDE "B" BOTTOM
design Claude
drawing Claude

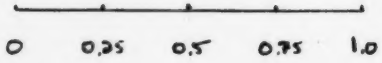
FOR MEASURES, REFER TO SIDE "A" BOTTOM.

Claude
15 juin 88. (4)

Side "B" top
design Claude
drawing Claude.

FOR MEASURES, REFER
TO SIDE "A" top.





Claude
15 JAN. 88

B) **Instantaneous Dust Sampler**

The instantaneous sampler was designed from 1 12" long, 4" diameter galvanized steel tube fitted with a spring-loaded cover at each end. A push and pull type solenoid valve was welded to the middle of the tube, and chains extended from the two cover plates to the solenoid. In the open position, the shaft of the solenoid is fitted with the chain extension which keeps the covers open. Once the solenoid is activated, the shaft is pulled down inside the magnetic coil, and the chains are released; the covers are pulled back in the closed position.

The following diagram is a schematic of the chamber as supplied by H. Fontaine Ltd. to NTC (the solenoid is not shown). A data sheet of Guardian Solenoids, which include the specifications of the solenoids chosen (marked by an asterix), is also provided.

Fontaine ltée

VANNES MURALES & POMPES SUBMERSIBLES D'ÉGOUT

À: CENTRE DE RECHERCHE NORANDA

ATTN.: Mr GOSSELIN

No. FAX.: 1-514-697-6640

DE: François FONTAINE

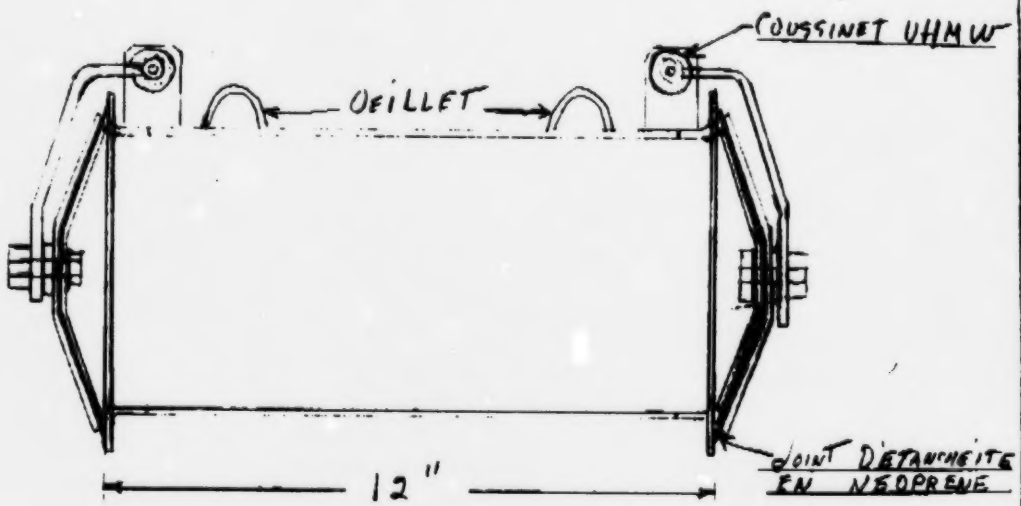
DATE: 17/06/88

NOMBRE DE PAGE(S) SUIVANT CELLE - CI : 0

VOTRE REF.: MINE DOSSIER:

NOTRE REF.: DOSSIER:

MATÉRIEL A.I. 304



3 UNITÉS 4" DIAMÈTRE PRIX UNIT. #260

3 UNITES 6" DIAMÈTRE PRIX UNIT #525

TAXES EXTRA + 8% FED + 9% PROV.

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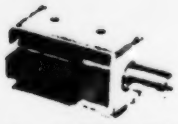
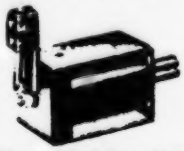
GUARDIAN® SOLENOIDS

PULL TYPE



No. 11 AC or DC*

Box-frame. Push and pull types. Coil construction: Uni-Guard* II molded bobbin and coil cover. Termination: 0.187" QC lugs. L-1⅞"—W-1⁹⁄₁₆"—H-1⁹⁄₁₆"



No. 11S AC or DC*

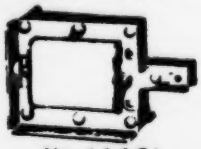
Same as No. 11. Pull type with 10A SPDT switch. Switch extends 1³⁄₁₆" above frame, ²⁵⁄₆₄" wide

No. 11HD AC or DC*

Heavy duty box-frame. Coil construction: Uni-Guard* II molded bobbin and coil cover. Termination: 0.187" QC lugs. L-2⅛"—W-1⁹⁄₁₆"—H-1¼"

No. 12 AC*

High efficiency laminated model. Coil finish: Acetate yarn coalesced with acetone. Termination: External leads. L-1⅝"—W-1¼"—H-1⁷⁄₁₆"



No. 14 AC*

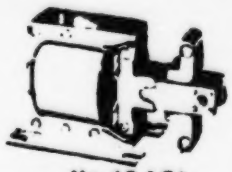
High efficiency laminated model. Coil finish: Acetate yarn coalesced with acetone. Termination: External leads. L-2⁷⁄₁₆"—W-1¹³⁄₁₆"—H-2¹⁄₁₆"

No. 16 AC*

High efficiency laminated model. Coil finish: Uni-Guard* II molded polyester. Termination: Dual purpose—solder lug and 0.187" QC. L-1⅝"—W-1¼"—H-1½"

Guardian No.	Duty	Coil Voltage	Ohms	Lifts and Strokes 25°C (Minimum)	Lifts and Strokes 25°C (Maximum)	Shpg. Wt. oz.
11	Inter	24AC	3.5	31 oz. at ⅛"	24 oz. at ¾"	5
11	Cont	24AC	8	15 oz. at ⅛"	10 oz. at ¾"	5
11	Inter	120AC	85	31 oz. at ⅛"	24 oz. at ¾"	5
11	Cont	120AC	200	15 oz. at ⅛"	10 oz. at ¾"	5
11	Inter	6DC	2	60 oz. at ⅛"	3 oz. at ¾"	5
11	Cont	6DC	4.5	40 oz. at ⅛"	1.5 oz. at ¾"	5
11	Inter.	12DC	8	60 oz. at ⅛"	3 oz. at ¾"	5
11	Cont.	12DC	18	40 oz. at ⅛"	1.5 oz. at ¾"	5
11	Inter	24DC	31	60 oz. at ⅛"	3 oz. at ¾"	5
11	Cont	24DC	72	40 oz. at ⅛"	1.5 oz. at ¾"	5
11S	Inter	120AC	85	31 oz. at ⅛"	24 oz. at ¾"	5.5
11S	Cont	120AC	200	15 oz. at ⅛"	10 oz. at ¾"	5.5
11S	Inter	24DC	31	60 oz. at ⅛"	3 oz. at ¾"	5.5
11S	Cont	24DC	72	40 oz. at ⅛"	1.5 oz. at ¾"	5.5
11HD	Inter	120AC	75	30 oz. at ⅛"	13 oz. at 1"	8
11HD	Cont	120AC	165	15 oz. at ⅛"	5 oz. at 1"	8
11HD	Inter.	12DC	7.2	60 oz. at ⅛"	1.5 oz. at ⅞"	8
11HD	Cont.	12DC	17	40 oz. at ⅛"	2.5 oz. at ⅞"	8
11HD	Inter	24DC	24	60 oz. at ⅛"	1.5 oz. at ⅞"	8
11HD	Cont	24DC	68	40 oz. at ⅛"	2.5 oz. at ⅞"	8
12	Inter	120AC	100	48 oz. at ⅛"	9 oz. at ⅞"	6
12	Cont	120AC	150	28 oz. at ⅛"	6 oz. at ⅞"	6
14	Inter	120AC	11	132 oz. at ⅛"	56 oz. at 1½"	9
14	Cont	120AC	18	96 oz. at ⅛"	112 oz. at 1½"	9
16	Inter	120AC	41	110 oz. at ⅛"	36 oz. at ¾"	7.5
16	Cont	120AC	85	63 oz. at ⅛"	15 oz. at ¾"	7.5
16	Inter	240AC	200	110 oz. at ⅛"	36 oz. at ¾"	7.5
16	Cont	240AC	350	63 oz. at ⅛"	15 oz. at ¾"	7.5
18	Inter	120AC	8.8	336 oz. at ⅛"	190 oz. at ⅞"	16.5
18	Cont	120AC	19.7	152 oz. at ⅛"	90 oz. at ⅞"	16.5
18	Inter	240AC	45	336 oz. at ⅛"	190 oz. at ⅞"	16.5
18	Cont	240AC	78	152 oz. at ⅛"	90 oz. at ⅞"	16.5
22	Inter	120AC	590	13.5 oz. at ¹⁄₁₆"	2.5 oz. at ½"	1.75
22	Cont	120AC	980	7 oz. at ¹⁄₁₆"	1 oz. at ½"	1.75
22	Inter	6DC	4	17 oz. at ¹⁄₁₆"	2 oz. at ⅜"	1.75
22	Cont	6DC	9	11 oz. at ¹⁄₁₆"	1 oz. at ⅜"	1.75
22	Inter.	12DC	16	17 oz. at ¹⁄₁₆"	2 oz. at ⅜"	1.75
22	Cont.	12DC	36	11 oz. at ¹⁄₁₆"	1 oz. at ⅜"	1.75
22	Inter	24DC	60	17 oz. at ¹⁄₁₆"	2 oz. at ⅜"	1.75
22	Cont	24DC	144	11 oz. at ¹⁄₁₆"	1 oz. at ⅜"	1.75
24	Inter	120AC	310	20 oz. at ¹⁄₁₆"	4 oz. at ⅜"	5
24	Cont	120AC	500	15 oz. at ¹⁄₁₆"	2 oz. at ⅜"	5
24	Inter.	12DC	13	28 oz. at ¹⁄₁₆"	3 oz. at ½"	5
24	Cont.	12DC	28.8	15 oz. at ¹⁄₁₆"	1.5 oz. at ½"	5
24	Inter	24DC	52	28 oz. at ¹⁄₁₆"	3 oz. at ½"	5
24	Cont	24DC	114	15 oz. at ¹⁄₁₆"	1.5 oz. at ½"	5
24S	Inter	24DC	52	28 oz. at ¹⁄₁₆"	3 oz. at ½"	5.5
24S	Cont	24DC	114	15 oz. at ¹⁄₁₆"	1.5 oz. at ½"	5.5
26	Inter	120AC	140	32 oz. at ¹⁄₁₆"	2 oz. at ⅜"	6
26	Cont	120AC	250	15 oz. at ¹⁄₁₆"	6 oz. at ⅜"	6
26	Inter.	12DC	8	44 oz. at ¹⁄₁₆"	3 oz. at ⅜"	6
26	Cont	12DC	20	24 oz. at ¹⁄₁₆"	3 oz. at ½"	6
26	Inter	24DC	33	44 oz. at ¹⁄₁₆"	3 oz. at ⅜"	6
26	Cont	24DC	85	24 oz. at ¹⁄₁₆"	3 oz. at ½"	6
28	Inter	24AC	7.5	26 oz. at ¹⁄₁₆"	5 oz. at ½"	5
28	Cont	24AC	17.4	15 oz. at ¹⁄₁₆"	4 oz. at ½"	5
28	Inter	120AC	220	26 oz. at ¹⁄₁₆"	5 oz. at ½"	5
28	Cont	120AC	400	15 oz. at ¹⁄₁₆"	4 oz. at ½"	5
28	Inter.	6DC	3.3	40 oz. at ¹⁄₁₆"	3 oz. at ½"	5
28	Cont.	6DC	7.7	23 oz. at ¹⁄₁₆"	2 oz. at ½"	5
28	Inter.	12DC	13	40 oz. at ¹⁄₁₆"	3 oz. at ½"	5
28	Cont.	12DC	27	23 oz. at ¹⁄₁₆"	2 oz. at ½"	5
28	Inter.	24DC	50	40 oz. at ¹⁄₁₆"	3 oz. at ½"	5
28	Cont.	24DC	104	23 oz. at ¹⁄₁₆"	2 oz. at ½"	5

*Recognized under the Component Program of Underwriters' Laboratories, Inc.



No. 18 AC*

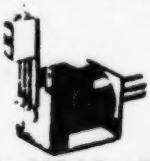
High efficiency laminated model. Coil finish: Acetate yarn coalesced with acetone. Termination: Solder lugs. L-2½"—W-1¹³⁄₁₆"—H-2³⁄₃₂"

No. 22 AC or DC*

Box-frame. Coil construction: Uni-Guard* II molded bobbin and coil cover. Termination: 0.110" QC lugs. L-1⁹⁄₃₂"—W-¾"—H-¾".

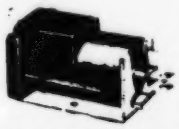
No. 24 AC or DC*

U-frame. Coil construction: Uni-Guard* II molded bobbin and coil cover. Termination: 0.187" QC lugs. L-1¼"—W-²⁷⁄₃₂"—H-1".



No. 24S AC or DC*

Same as No. 24 with 10A SPDT switch. Switch extends ²⁹⁄₃₂" above frame, ²³⁄₆₄" wide.



No. 28 AC or DC*

U-frame. Coil construction: Uni-Guard* II molded bobbin and coil cover. Termination: 0.187" QC lugs. L-1¾"—W-²⁷⁄₃₂"—H-1¹³⁄₁₆".

No. 28 AC or DC*

Box-frame. Push and pull types. Coil construction: Uni-Guard* II molded bobbin and coil cover. Termination: 0.187" QC lugs. L-1⅛"—W-1⁹⁄₃₂"—H-1³⁄₁₆".

C) **High Volume Air Samplers**

Two high-vol air samplers from Staplex were purchased for the project. The samplers are capable of providing a flow rate of 70 CFM depending on the filter type. The filters chosen were rated for 36-40 CFM at 4" diameter and had a 95% collection efficiency of particles .5 microns and over.

The next five pages represent the owner manual of the high-vol sampler.

Owner's Manual

Operating Instructions
for your new

Staplex® Air Sampler

© The Staplex Company, Inc.

SAFETY PRECAUTIONS:

- Read the accompanying use and care instructions and safeguards for this appliance before you use it.
- **WARNING: DO NOT OPERATE THIS AIR SAMPLER IN EXPLOSIVE ATMOSPHERES OR IN THE PRESENCE OF EXPLOSIVE OR FLAMMABLE FUMES; DO NOT ALLOW ELECTRICAL COMPONENTS TO BECOME WET.**
- Use only those supplies, attachments, replacement parts, or accessories recommended for use with this air sampler in these instructions.
- Turn air sampler OFF when loading, unloading, attaching or removing filters or accessories.
- Do not operate this air sampler without a filter or other recommended sampling accessory. Make certain that filters do not become overly saturated to restrict air flow or break up during operation.
- Unplug from outlet when not in use and before cleaning or servicing. Grasp plug, not cord, when disconnecting air sampler from outlet.
- Do not operate an air sampler with a damaged cord or plug or after the sampler malfunctions or has been damaged in any manner.
- Keep fingers, jewelry, hair, etc. away from any moving parts.
- Electrical appliances should only be used as instructed in the use and care instructions.
- Should your air sampler ever require service, ask service person to verify that a safety check has been performed on the repaired appliance.

Staplex

High Volume Air Samplers

- **Samples down to .01 micron**
- **Indoor or outdoor use**
- **Spot or continuous monitoring**
- **Portable and lightweight**
- **Complete accessories available**

Model TFIA, TFIA-2, TFIA-4

Description

Portable Air Sampler for indoor and outdoor sampling for Air Pollutants: Radioactive Particles: Industrial, Municipal and Governmental Tests and Studies: Smoke and Smog: Atmospheric Conditions: Mine Air Hazards: Factory Dusts: Chemical, Radiological and Toxicological Analyses, as well as innumerable other types of Research and Testing.

Principle of Operation

Air is drawn through a filter by a high speed rotary motor. The prime purpose is for sampling large volumes of air for particulate matter by means of various types and sizes of filter papers including Glass Fiber Filter Media.

Particle Size Range

Particulate matter all sizes down to submicron detectable range as small as .01 micron.

Concentration Range

Full surface of filters from 4" Diameter to 8" x 10".

Sampling Scope

Method: Samples large volumes of air for particulate matter by means of a filter
Flow Rate: Up to 70 CFM depending on filter See Chart A
Collection Efficiency: Down to .01 micron See Chart A

Standard Features

Universal motor, Pump, Variable Orifice Flowmeter calibrated 0-70 CFM or 0-2 CMM: complete with 4" diameter Filter Holder Assembly, Filter Support Rod and Stainless Steel Mesh Adapter All Staplex Air Samplers are designed and engineered for universal use resulting in a rugged instrument For added versatility they are equipped with carrying handle allowing Sampler to be used portably when required

When normal currents are not available Model TFIA-4, 24 Volts DC, is ideal for remote field use with batteries.

Analysis of Collected Samples

Gravimetric, weighing, taring, ashing, spectrograph, atomic absorption, comparator, microscopic count, chromatography, atomic colorimetric assay, and gamma-ray spectroscopy, x-ray fluorscopy and neutron activation etc., depending upon type of analysis required, which are available to identify pollutants and measure their concentrations.

Standard Models

Model TFIA: - 110-125 Volts AC/DC, 50-60 Hz
Model TFIA-2: - 220-240 Volts AC/DC, 50-60 Hz
Model TFIA-4: - 24 Volts DC
Other special models available.
Dimensions: 8½" x 7½" x 7½"
Carrying weight: 10 lbs.
Construction: Sturdy Lightweight Dural Main Housing

Staplex **Air Sampler Division**
777 Fifth Avenue, Brooklyn, New York 11232-1695, USA
718 768-3333

CHART A

Staplex Filters

for Staplex Model TFIA, TFIA-2, TFIA-4 High Volume Air Samplers

TYPE FILTERS	FLOW RATE, C.F.M.	CHARACTERISTICS
TFA41, 4" Diameter	20-26 approx.	Ashless. 95% collection efficiency of 1 micron particles. Easily countable for Alpha particles, obtaining 70% count and a penetration absorbtion of approximately 30%. Good efficiency for industrial dusts and for particulate matter size 10 microns and under to submicron to .01 micron. Sampler may be operated for approximately 1 hour without overheating.
TFAGF41 Glass Fiber, 4" Diam.	20-26 approx.	Same Specs. As Above. Also see data on Glass Fiber Filters Below.
TFA69, 6" x 9"	50-58 approx.	Same Specs. As TFA41, except Sampler may be operated for approximately 24-48 hours.
TFAGF69 Glass Fiber, 6" x 9"	50-58 approx.	Same Specs. As Above. Also see data on Glass Fiber Filters below.
TFA810, 8" x 10"	60-68 approx.	Same Specs. As TFA69.
TFAGF810 Glass Fiber, 8" x 10"	60-68 approx.	Same Specs. As Above. Also see data on Glass Fiber Filters below.
TFA2133, 4" Diameter	36-40 approx.	Moderate flow rate. Moderate resistance buildup. 95% Collection Efficiency of particles .5 microns and over. Countable for Beta Radiation. Sampler may be operated for one hour or more depending upon saturation without significantly overheating.
TFA'S', 4" Diameter	66-70 approx.	Pleated cellulose paper filter. High flow rate. Physically strong. Low resistance buildup. For particulate matter size .10 microns and over. Countable for Gamma radiation. Especially recommended wherever long sampling periods are required at low dust loading. Can be operated continuously with the filter changed every 72 hours. A normal sample was obtained when using this paper for 72 hours and represents a concentration of as low as 10^{-8} mg. of the material of interest in a cubic foot of air.

GLASS FIBER FILTER DATA

Glass Fiber Filters are especially recommended wherever gravimetric weighing analysis may be required because of their nonhygroscopic properties, i.e. they will maintain constant weight under wide-ranging conditions of ambient humidity. Their excellent loading characteristics make them ideal for routine air monitoring and for specialized monitoring of solid pollutants, microrganisms, oil and acid smokes etc. They are particularly recommended where higher efficiency collection of fine particles is required. They exhibit higher particle capacity then cellulose filters. Their fine optical characteristics make them ideal for sensitive and accurate measurement of collected smoke particle. Used especially for on-the-spot visual examination and instrumentation. Glass Fiber Filters have a higher density then paper filters and can tolerate a far wide useful temperature range.
Available normally with organic binder; also available without binder and should be so specified.

Standard Glass Fiber Filter Media with organic binder will withstand temperatures up to 220-250°C. Composition of the Glass Fiber Filter is of such a nature that the finely woven texture of microfilaments of glass creates the highest sampling efficiency. The efficiency of the Glass Fiber Filters at the relative flow rate for particles as small as .3 micron is 99.98%. The standard Glass Fiber Filter media contains a small percent of organic binder (.03%) which allows additional strength for ease in handling and sampling procedures.

Glass Fiber Filter Media which are also available without organic binder should be so specified when ordering. The retention and sampling efficiency is equal and identical to the specification listed above, the only variation occurring in the heat resistance which is as follows:

Without organic binder, up to approximately 470-490°C
With organic binder, up to approximately 220-250°C

Due to technological advances, specifications subject to change without notice or obligation

Staplex Air Sampler Division
777 Fifth Avenue, Brooklyn, New York 11232-1695, USA

Parts List

Staplex Air Sampler Division
777 Fifth Avenue, Brooklyn, New York 11232-1695, USA
718 768-3333
Toll free 800-221-0822
Telex 429015

Model TFIA, TFIA-2, TFIA-4
High Volume Air Samplers

PART NO.	DESCRIPTION	NO. REQUIRED
1	Cord set assembly (2 conductor)	1
1A	3 Conductor cord set ass'y with ground plug	
1B	Cord set assembly with switch (2 conductor)	
1C	3 Conductor cord set assembly with switch and ground plug	
2	Base gauge plate hexagon lock nut	4
3	Base gauge plate screw	4
4	Main housing	1
5	Carrying handle	1
5A	Carrying handle D-ring	2
6	Outer motor cap	1
7	Current toggle switch	1
8	Filter holder "O" ring	1
9	Filter holder	1
10	Tightening ring	1
11	Threaded mounting ring	1
11A	Threaded mounting ring screws	6
14	Motor - 110 Volts	1
14A2	Motor - 220 Volts	1
14B4	Motor - 24 Volts D.C.	1
15	Motor screw	3
15A	Motor nut	3
16	Base gauge plate	1
17	Pressure indicator gauge (flowmeter)	1
18	Filter rod	1
19	Motor grommet	1
20	Screen mesh support 4" diameter	1
22	Pressure indicator gauge Red Float	1
23	Base gauge lock screw	1
24	Top gauge adjusting screw	1
25	Top gauge adjusting nut	1
6790-3	Carbon brush assembly	2
26	Brush holder screw	2
0-5490	Brush holder clamp (certain series only)	2
50-7950	Brush holder clamp screw (" " ")	4

PARTS LIST FOR STAPLEX FILTER HOLDER ASSEMBLY, PART NO. SH810

30	Filter holder funnel and tightening ring	1
32	Round rubber disk	1
33	Rectangular tightening frame	1
34	Rectangular rubber sealing disk	1
35	Knurled locking screw	4
36	Knurled locking screw washer	4
37	Tightening washer and holding ring assembly	4

NOTE: When ordering parts, give complete Model, serial number and letter, AND color of brush holder. Photocopy of motor brush is also helpful.

Staplex® **Air Sampler Division**

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TR-1 Tripod

Assembly Instructions

1) Remove Staplex **Model TR-1** Tripod from carton. Remove Mounting Plate (A) from packaging bag. All mounting hardware is located in the appropriate holes of the Mounting Plate.

2) Spread Legs (B) of the Tripod to open position as shown in the diagram. Stand Tripod on flat surface.

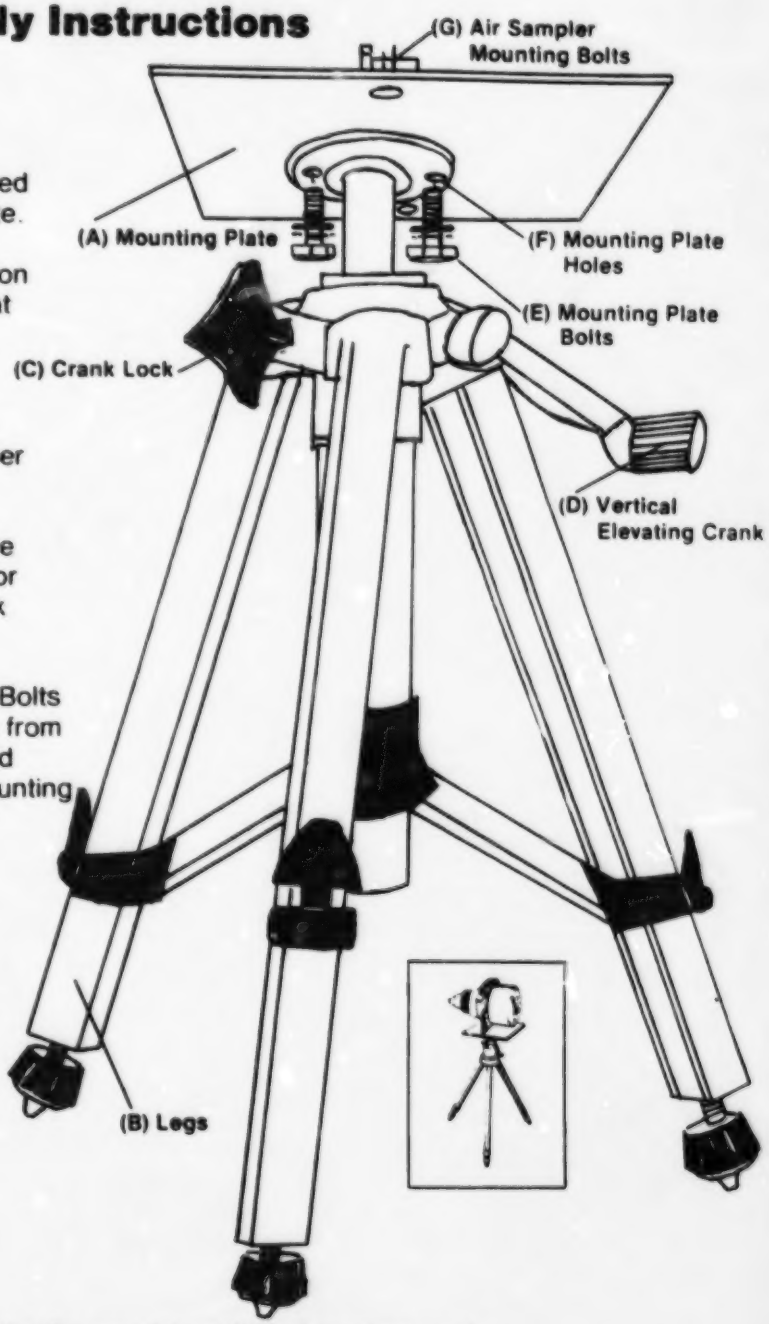
3) Crank Lock (C) is shipped in locked position. To unlock, turn Crank Lock counterclockwise. To lock after reaching proper height, turn clockwise.

4) Turn Vertical Elevating Crank (D) in clockwise rotation for about 15 turns to ready Tripod for assembling Mounting Plate. Turn Crank Lock to lock position.

5) Remove the two assembled Mounting Plate Bolts (E) complete with lockwashers and washers from the Mounting Plate Holes (F). The assembled Bolts are shipped hand-tightened on the Mounting Plate to facilitate their removal.

6) Place Mounting Plate on top of Tripod and position so that the two Mounting Plate Holes align with the two holes in the round disk at the top of the Tripod as shown.

7) Insert each set of Mounting plate Bolts complete with lockwashers and washers as shown into the Mounting Plate Holes from the underside of the Tripod. Turn Bolts until they catch thread in Mounting Plate and tighten with wrench. Tripod is now assembled.



An additional set of Air Sampler Mounting Bolts (G) complete with lockwashers and washers are supplied and taped on top side of the Mounting Plate for the purpose of mounting Staplex Air Sampler to Tripod with two corresponding threaded holes provided in Staplex Air Sampler for this purpose.

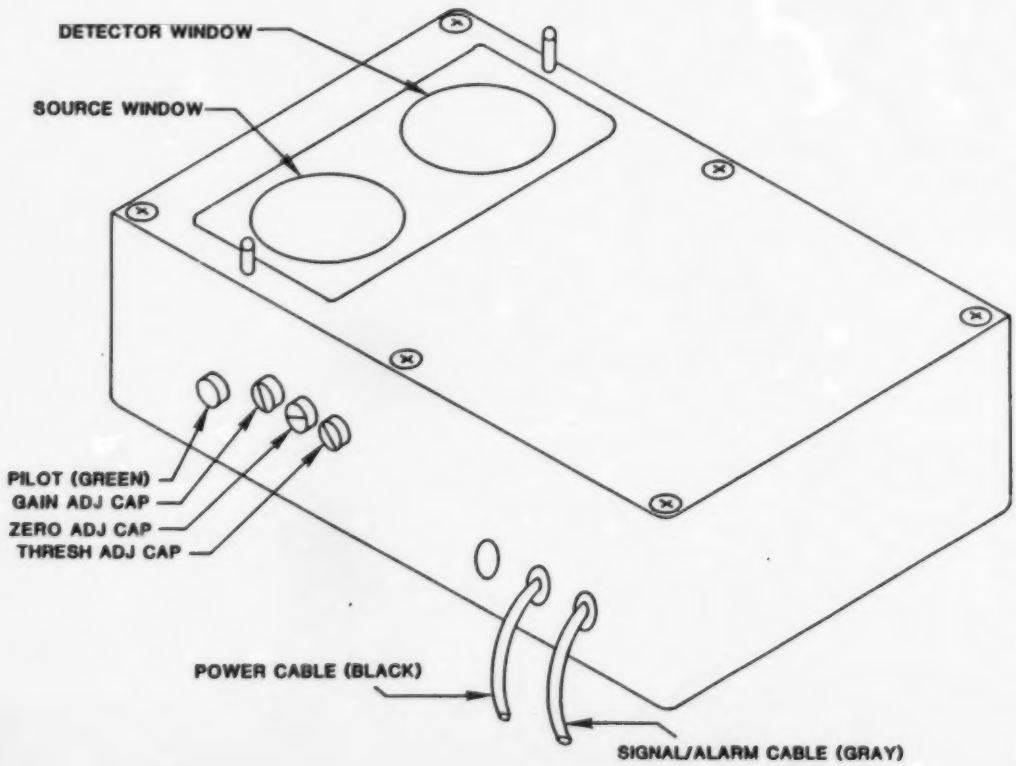
D) **Ras-1 (or Ras-2) Dust Probe from Mie Instrument**

The Ras-1 is a compact airborne particulate concentration transducer whose operating principle is based on the detection of scattered electromagnetic radiation in the near infrared. It uses a pulsed GaA1As light-emitting source, which generates a narrow-band emission entered at 880 nm. This source is operated at an average output power of about 6 mW. The radiation scattered by airborne particles is sensed over an angular range of approximately 45^{o} to 95^{o} from the forward direction by means of a silicon-photo voltaic hybrid detector with internal low-nois preamplifier. An optical interference-type filter is incorporated to screen out any light whose wavelength differs from that of the pulsed source.

Air surrounding the Ras-2 passes freely through the open aerosol sensing chamber of air transport caused by convection, circulation, ventilation, etc.. The Ras-1 requires no pump for its operation, and the scattering sensing parameters have been designed for preferential response to the particle size range of 0.1 to 10 micrometers, ensuring high correlation with standard gravimetric measurements of both the respirable and inhalable fractions.

The Ras-1 provides an analog signal output directly proportional to the concentration of airborne particles.

The next diagram provides an external view of the Ras.



E) **Vacuumed Vessels**

Four stainless steel cylinders of 500 mL each were purchased by NTC and fitted with 1/8" orifice solenoid valves. The cylinders were first vacuumed with a diaphragm pump and then installed underground at various locations near the blast, fixed to the roof of the tunnel. The solenoids were powered for a period of 30 seconds during the blast to sample the environment.

APPENDIX F

BMS-M BLAST SPRAY TIMER AND FIRE NOZZLE

FEB 6, 1989

DON GAGNON
TRAINING CO-ORDINATOR

BLAST SPRAY TIMER

COMPONENTS : - PROGRAMMABLE TIMER , (OMRON H3CA-A)
- 12 VDC SOLENOID VALVE , (SKINNER 70CN10 ZAN)

POWER SUPPLY ; 4 X 6 VDC DRY CELL BATTERIES (TYPE 918X)

DESCRIPTION OF DEVICE :

Unit is fabricated with all wiring inside a 12"W x 14"H x 6"D enclosure which also houses the four dry cell batteries. Piping for the solenoid valve is within the box, this results in a very portable and sturdy unit. Battery power allows the unit to operate away from power lines.

The programmable timer is set to signal ON\OFF (program C . This starts the timer when the signal changes state from closed to open. The time delay for the relay is set using thumbwheel switches on the timer in SEC\MIN\HRS. The time setting now in use is 5 minutes.

The normally open contacts of the timer relay are wired to the solenoid valve which controls water flow to a spray nozzle at the blast site. Typical installation would place the timer box control approximately 100 feet (30 metres) back from the blast face.

HOOKING UP TIMER :

The unit is secured onto the tunnel wall using the hangers to position the box onto a rockbolt, pipe or screen. The box could also be set on the ground.

A 1" hose is attached from the water line to the inlet of the timer box. Another hose is attached to the output end and ran to the water spray, which is secured to the back of the blast site.

After the blast is loaded, a loop of wire (lead blasting wire) is taped alongside a section of detonating cord and the ends are secured on the front panel of the box using the two wing nut terminals.

This short section of detonating cord is attached to the blast via two delay caps (# 12 long delay) . The electric caps are attached to the blast cord to complete the blast connection.

After all blast preparations are made, the unit is activated by setting the main switch to "on". The green LED beside the switch will be lit, the other green LED will be lit showing that the solenoid is activated. At this point water should be flowing through the water spray and onto the blast site.

At the end of the pre-set time delay, the solenoid will be de-activated, stopping the water flow.

This procedure will verify the operation of the unit, and that all connections were properly made.

The water flow may be stopped by pressing the reset push button on the front panel to cycle the timer to off.

NOTE; There are no electrical connections between the blast and the timer box.

LOW BATTERY INDICATOR :

If the battery voltage drops below 10.2 VDC during operation the warning red LED on the front panel will be lit. Operation of

the unit is still possible, batteries must be replaced as soon as possible.

Batteries must be connected in proper position for polarity

OPERATION :

When the blast is detonated, the lead wire signal line will be broken activating the timer for another cycle. The spray will be on for the set time then automatically stop. The power to the unit will remain "on" until the ON\OFF switch is set to "OFF".

CONCLUSION :

Water has been found to be very effective in controlling secondary explosions of Sulphide ore. Water reduces the gas temperatures created by the explosion, and allays dust as it is created. Proximity to the blast face is important for this to be effective, the spray must be pointed to the center of the blast, secured to the back approximately 10 to 15 feet back, and set to cover as much area as possible. Water flows should be in the range of 40 to 60 GPM. for large headings used for mechanized mining. To cover slash areas, multiple sprays may be required.

The use of a timer aids in controlling water usage without reducing the effectiveness of using large flows of water to eliminate sulphur blasts. The cost reduction by reduced water usage will pay for this unit in a short time.

The blast spray timer can also reduce dust levels throughout the underground workings in both sulphide and waste rock

readings. This type of system can also be supplied for use in mines and in other types of blasting.

Approximate cost - $300.00 / unit for parts

PARTS LIST

#	ITEM	DESCRIPTION	AMOUNT	BMS STOCK
1	ENCLOSURE	14 X 12 X 6"	1	NS
2	TIMER	OMRON H3CA-A	1	NS
3	SOCKET	11 PIN	1	141 1475
4	BATTERIES	6 VDC, DRY CELL	4	140 0422
5	SOLENOID	12 VDC (SKINNER 70ZN102AN)	1	NS
6	SWITCH	TOGGLE	1	053 1077
7	SWITCH	PUSHBUTTON, MOM.	1	RS275 1568
8	WIRE	RED 12 G.	-	110 0345
9	WIRE	BLACK 12 G.	-	110 0343
10	BOLTS	1/4" X 1" HEX NC	10	
11	NUTS	1/4" NC	12	
12	FLAT WASHERS	1/4"	16	
13	LOCK WASHERS	1/4"	10	
14	WING NUTS	1/4"	2	128 0275
15	SPUD	1" X 1"	2	121 0136
16	ZENER DIODE	5.6 V ECG 136A	3	
17	RESISTOR	270 OHM, 1/2 WATT	2	
18	RESISTOR	560 OHM	2	
19	DIODE	N- SERIES	2	
20	LED	GREEN RS 276 069	2	
21	LED	RED RS 276 068	1	
22	NIPPLE,PIPE	1" X 6"	2	
23	TERMINALS	ASSORTED		
24	TY WRAPS	6"		
25	EYE BOLTS	3/8"	2	128 0501
26	NUTS	3/8"	2	
27	HASP	4"	1	
28	PADLOCK	-	1	

DON GAGNON

TRAINING CO-ORDINATOR

BLAST SPRAY TIMER

SUMMARY OF HOOK UP AND OPERATION

1- DRILLED HOLES IN ROCK ARE LOADED WITH EXPLOSIVES A AND READIED FOR BLASTING

2- DETONATOR CAPS C ARE CONNECTED TO DETONATOR CORD B

3- TIMER BOX L IS SECURED TO THE TUNNEL WALL USING THE EYELETS K AND CONNECTED TO WATER LINE O VIA LENGTH OF HOSE P TO INLET W

4- A SPRAY NOZZLE M IS FASTENED TO THE ROOF AND CONNECTED TO TIMER BOX OUTLET X VIA LENGTH OF HOSE N

5- 2 DETONATOR CAPS D ARE ATTACHED TO CORDLINE B TO ACT AS DELAYS. THESE CAPS ARE SECURED TO THE SHORT SECTION OF CORD LINE E

6- A LOOP OF 22 GUAGE BLASTING WIRE J IS TAPED ALONGSIDE THE SHORT SECTION OF BLASTING CORD E

7- THE FREE ENDS OF THE WIRE LOOP J ARE ATTACHED TO THE TWO TERMINALS ON THE FRONT OF TIMER BOX L AT POINTS V

8- THE WATER LINE O IS OPENED TO CAUSE A FLOW OF WATER THROUGH HOSE P TO INLET W

9- THE TIMER IS TESTED BY SETTING THE SWITCH Q TO THE "ON" POSITION. GREEN LAMPS R (POWER ON) AND U (SOLENOID OPEN) WILL BE LIT. WATER WILL FLOW THROUGH HOSE N TO NOZZLE M AND CAUSE A SPRAY ONTO LOADED BLAST A

10- AT THIS POINT, PUSHBUTTON I MAY BE DEPRESSED TO RESET TIMER AND STOP THE WATER FLOW, OR, THE FLOW WILL CONTINUE UNTIL THE PRE-SET TIME HAS BEEN ELAPSED. GREEN LAMP R WILL BE ON, GREEN LAMP U WILL BE OFF.

11- IF THE BATTERY VOLTAGE AT ANY TIME GOES BELOW 10.3 VDC, THE RED LAMP S WILL BE LIT, BATTERIES MUST BE CHANGED AS SOON AS POSSIBLE.

12- THE FINAL BLAST PREPARATIONS ARE NOW MADE BY CONNECTING AN ELECTRIC CAP F TO THE SHORT SECTION OF CORD LINE E

13- T-E WIRES OF CAP F ARE CONNECTED TO THE MAIN LINE H AT I

14- WHEN BLASTING OCCURS, CURRENT FLOWS THROUGH LINE H CAUSING CAP F TO INITIATE CORD LINE E

15- THE DEALY CAPS D ARE INITIATED FOR THE RATED DELAY PERIOD. WIRE LOOP J IS SEVERED BY THE BLASTING OF CORD LINE E CAPS

15- cont. THIS SIGNALS TIMER IN BOX = TO OPEN THE INTERNAL SOLENOID VALVE AND RAISE WATER TO SPRAY

16- AFTER THE DELAY PERIOD, DELAY CAPS S IGNITE CORD LINE R TO SET OFF THE MAIN BLAST T

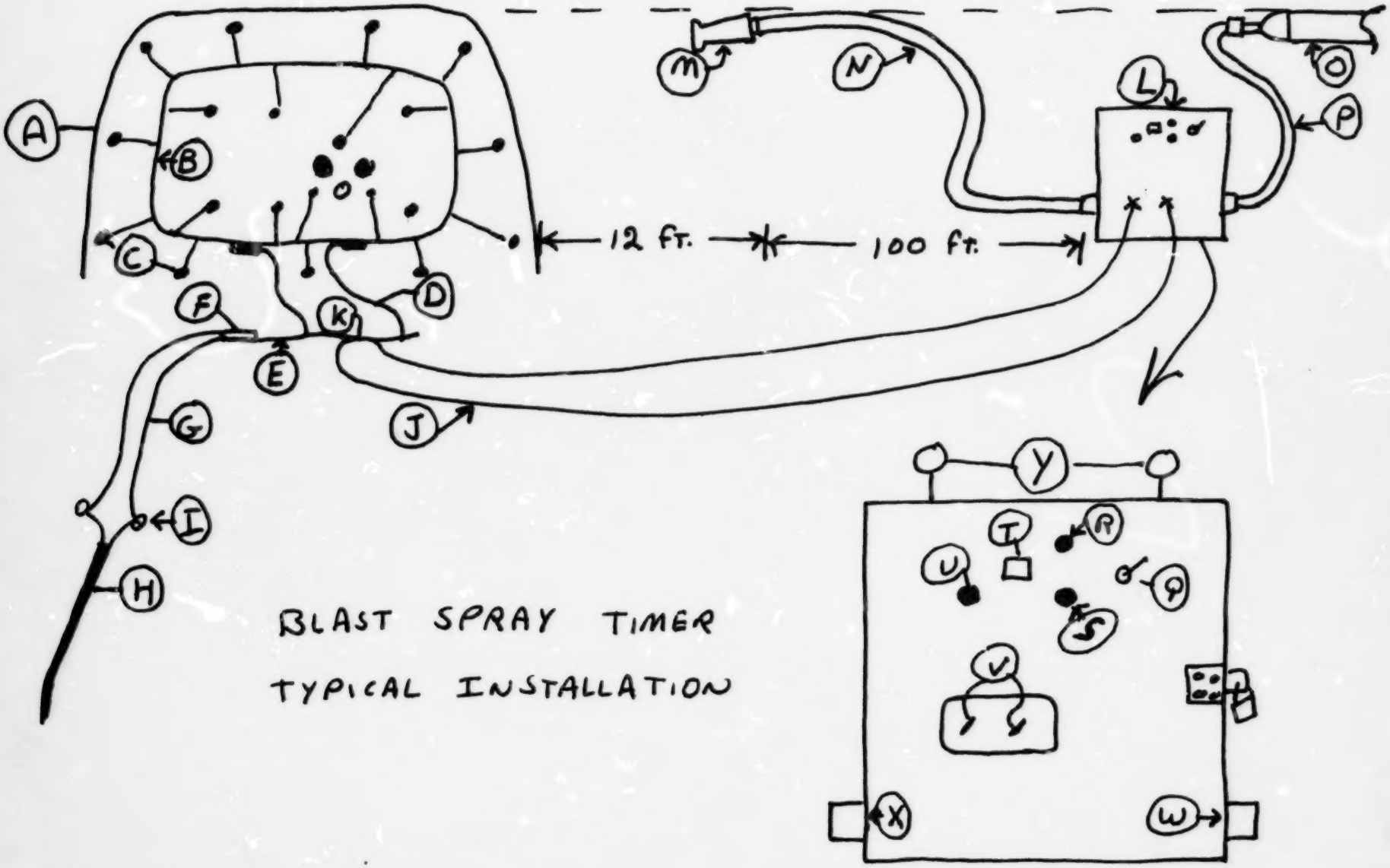
17- WHEN THE MAIN BLAST IS INITIATED, WATER FROM NOZZLE M IS FLOWING INTO THE BLAST AREA REDUCING GAS TEMPERATURES AND WETTING DOWN DUST PARTICLES. THIS WILL AID IN PREVENTING SECONDARY EXPLOSIONS

18- AFTER THE PRE-SET TIMING PERIOD, THE TIMER IN BOX = DEACTIVATES THE INTERNAL SOLENOID, STOPPING THE WATER FLOW

19- THE TIMER BOX IS REMOVED BY FIRST SETTING THE SWITCH U TO "OFF". DISCONNECT WIRES FROM TERMINALS V, AND DISCONNECT HOSES FROM INLET W AND OUTLET X

DON GAGNON

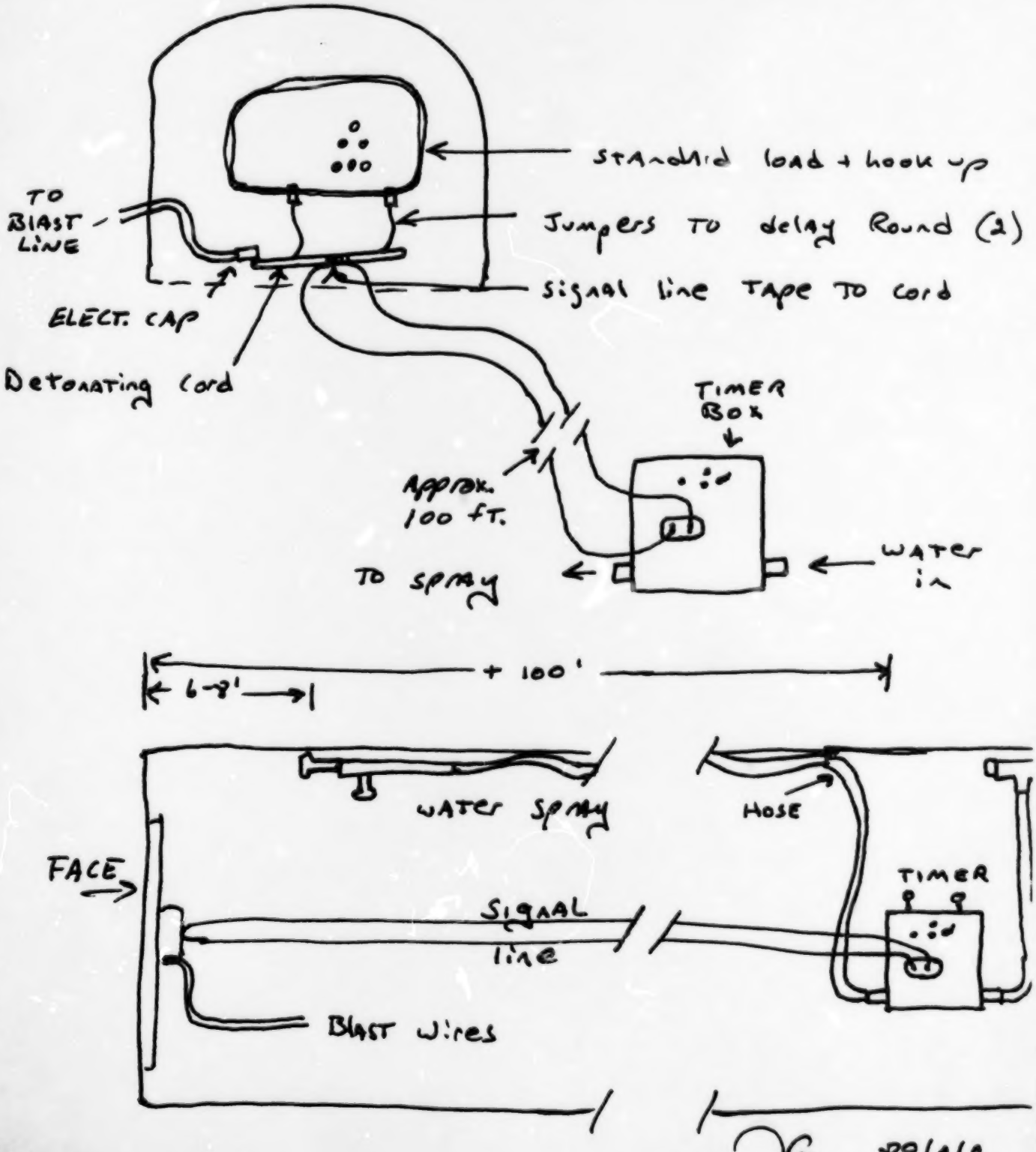
TRAINING CO-ORDINATOR
BRUNSWICK MINING



BLAST SPRAY TIMER

TYPICAL INSTALLATION

= TYPICAL BLAST HOOK UP =



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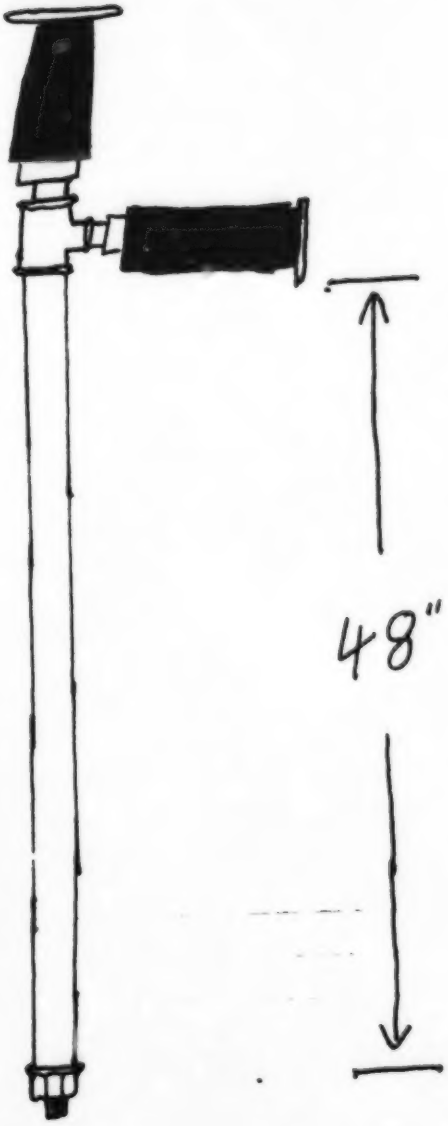
Fire Nozzle Spray

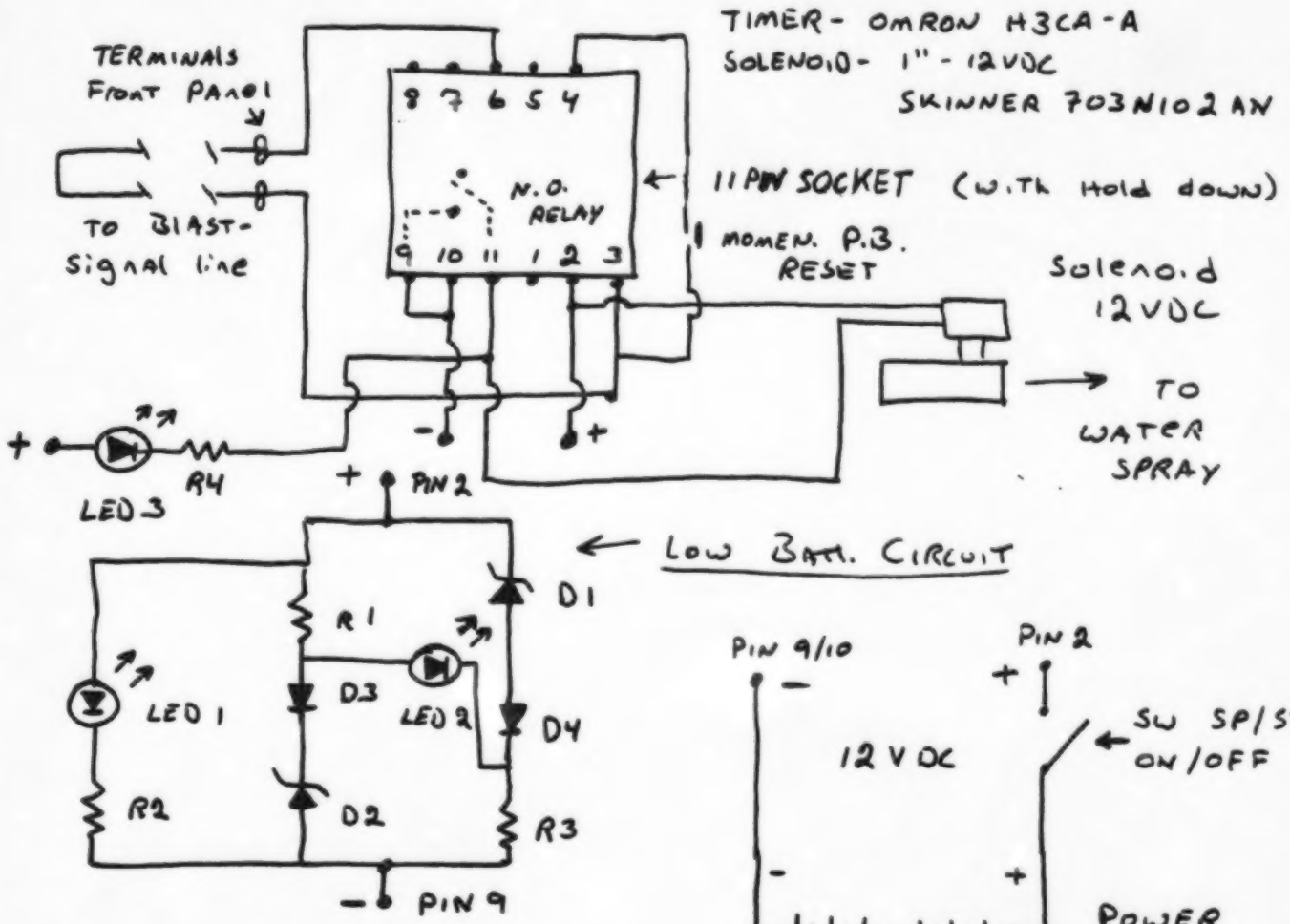


Parts List

Item	Amt.	Stock #
Fire Nozzle	2	137-2057
1½" x 1" Bushing	2	120-0007
1" pipe Tee	1	120-0471
1" closed nipple	2	120-0172
1" x 1" spud	1	121-0106
1" pipe 48" long	1	

= BLAST SPRAY TIMER =

WIRING DIAGRAM



D1, D2 ZENER 5.6 V, 1W
ECG 136A

D3, D4 Diode N—
R1, R3 270 Ω, 1/2 W
R2, R4 560 Ω, 1/2 W

LED 1	Green	RS 276 069	(POWER ON)
LED 2	RED	RS 276 068	(LOW BATT)
LED 3	Green	RS 276 069	(solenoid on)

LED 1, 2, 3 MOUNT ON FRONT PANEL OF BOX.

SW ON/OFF MOUNT ON FRONT PANEL

D Gagnon
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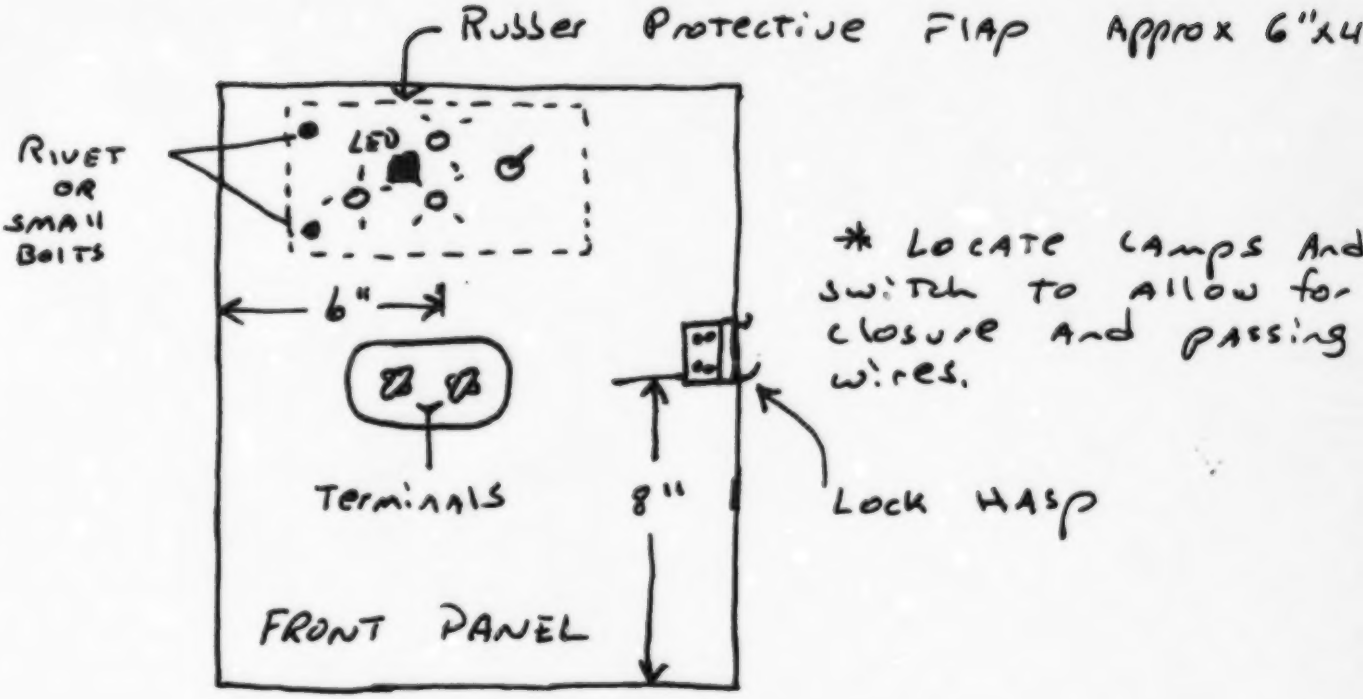
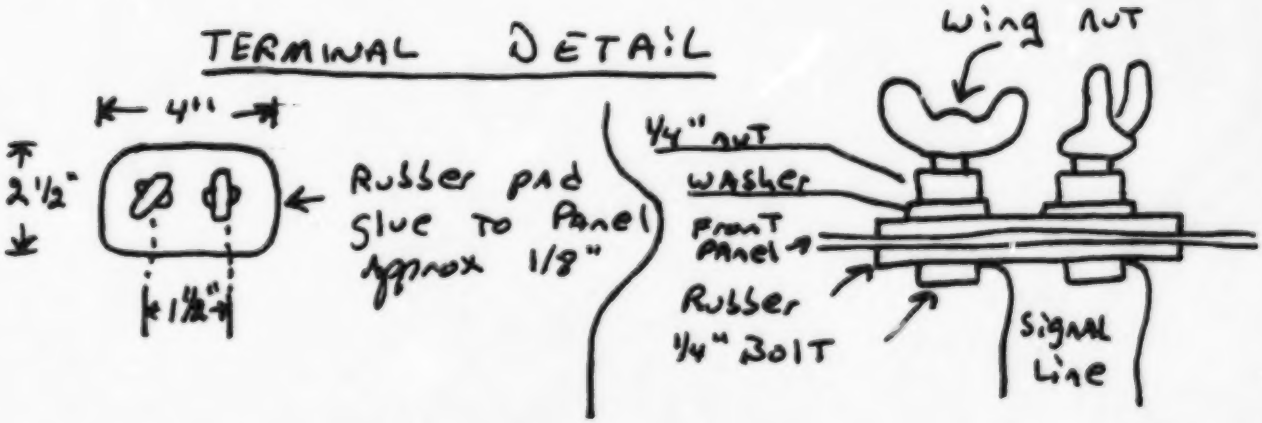
= BOX - ENCLOSURE =

FRONT PANEL



TERMINAL DETAIL



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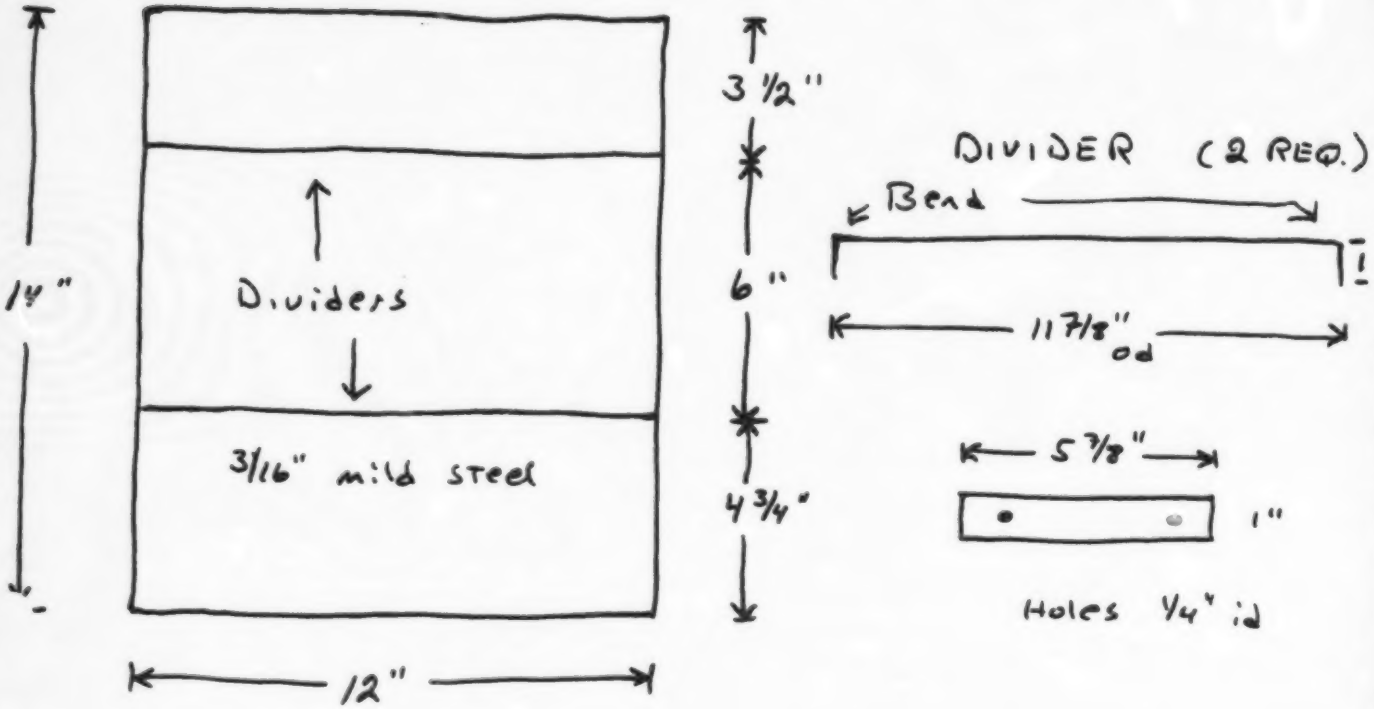
BOX - ENCLOSURE

DIVIDERS



Dividers mounted inside box with 1/4" x 1" Hex Bolts.

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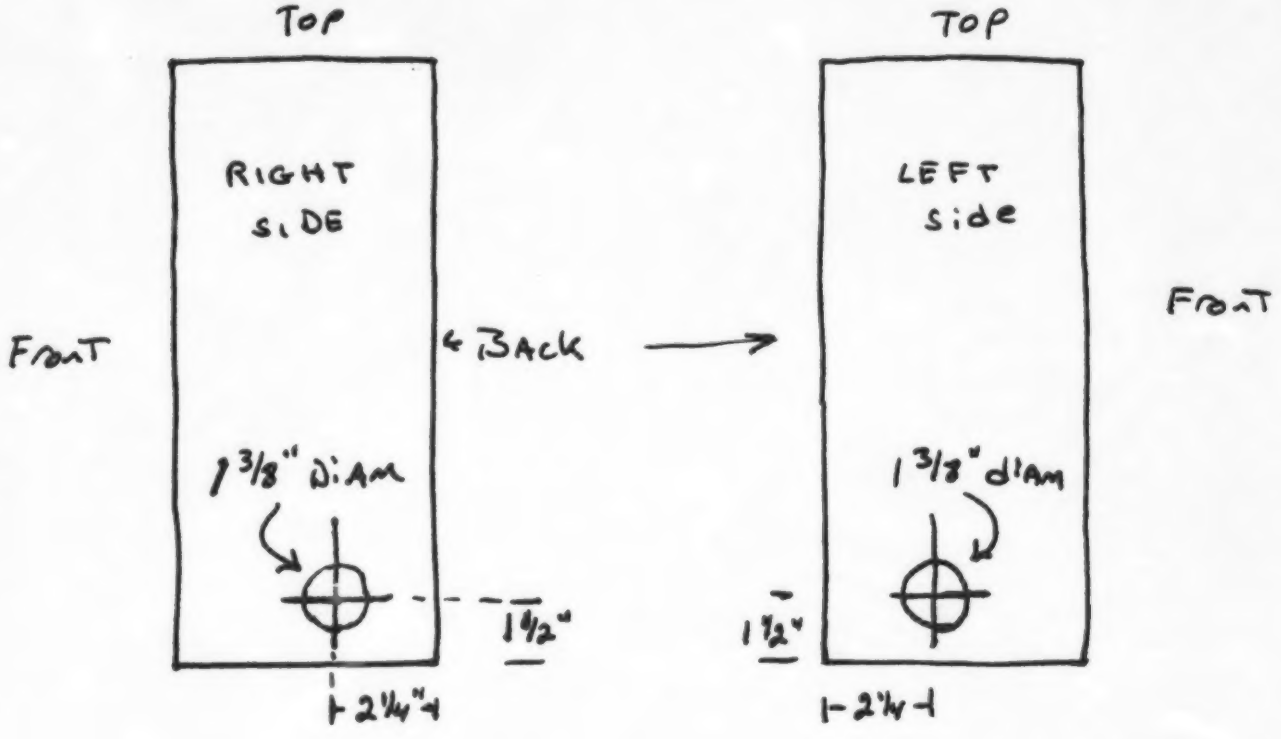
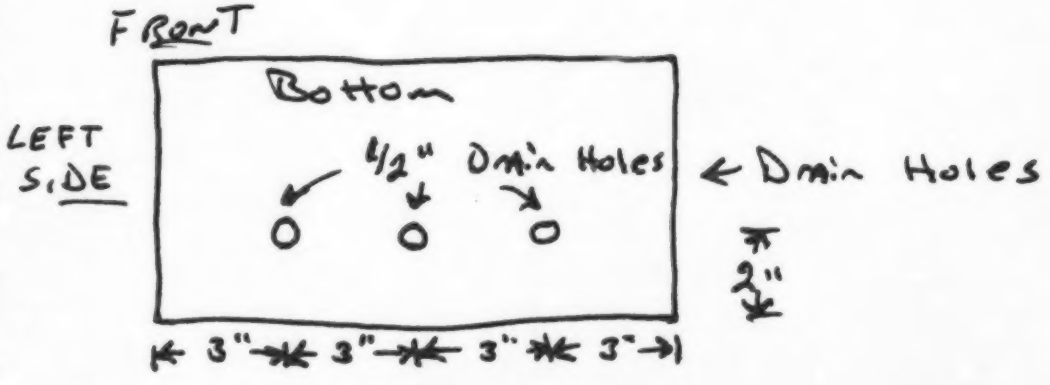
BOX - ECLOSURE CONT.





NOTE - Drill same pattern on REAR PANEL

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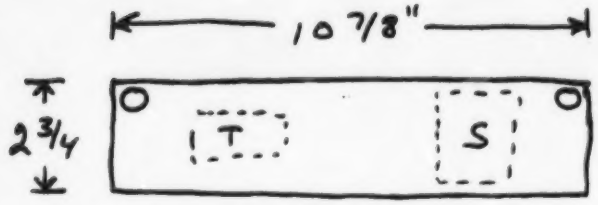
9/2/2

ATTACHING ELECTRONICS



T - Terminal strip
S - Socket (11 pin)

NOTE - CUT pc from backing plate THAT C/W BOX. SECURE 11 pin socke with 2 screws Through base.

ATTACK 4 position Terminal strip TO SECURE Power ON / low bATT. CIRCUIT ONTO PLATE.

PLATE held in place with 1 or 2 NUTS THAT c/w Box enclosure

Run wires TO ALLOW REMOVAL of PLATE from box for TESTING and repairs.

DG

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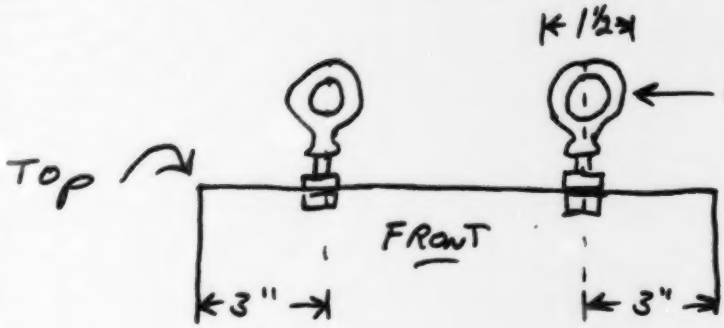
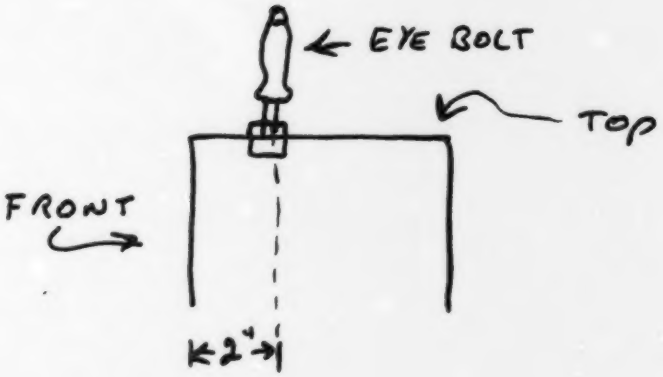
= BOX - ENCLOSURE =

* EYE BOLT - HANGERS



* used to secure Box to Drift wall on pipe, Bolts, screen etc. using TY WRAP chain wire etc..



OG

8/1/2/2

[redacted] H3CA-A
TIMER
TIME 99.9s to 9990H
VOLTS. 24 to 240VAC 12 to 240VDC

LOT No. 0617 QTY. 1

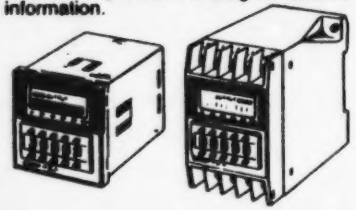
OMRON

Model **H3CA** SOLID-STATE TIMER

INSTRUCTION MANUAL

Model H3CA SOLID-STATE TIMER

This manual primarily describes precautions required in installing, wiring and handling. When using the timer, please refer to the pertinent catalog for detailed information.



OMRON TATEISI ELECTRONICS CO.

■ AVAILABLE TYPES

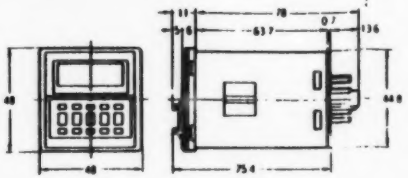
Operation/resetting system		Time-limit operation/self-resetting/external resetting*		Time-limit operation/self-resetting	Time-limit operation/self-resetting
Operation mode		8 operation modes (selectable)**		ON-delay operation	ON-delay operation
Terminal form		11-pin round socket	Front screw	8-pin round socket	8-pin round socket
Time-limit contact		SPDT		DPDT	SPDT
Instantaneous contact		–		–	SPDT
Equipped with control output ON/OFF and remaining time indicators	Surface mounting	H3CA-A (with P2CF-11 socket)	H3CA-FA	H3CA-8 (with P2CF-08 socket)	H3CA-8H (with P2CF-08 socket)
	Track mounting				
	Flush mounting	H3CA-A (with Y92F-30 adapter)	–	H3CA-8 (with Y92F-30 adapter)	H3CA-8H (with Y92F-30 adapter)

NOTES:
1. *The operation/resetting system depends on the selected operation mode. For details, see "TIMING CHARTS (OPERATION MODES)."
2. **The 8 operation modes are as follows:
   A: ON-delay operation
   B: Flicker operation
   C: Signal ON-/OFF-delay operation III
   D: Signal OFF-delay operation III
   E: Interval operation
   F: One-shot and flicker operation
   G: Signal ON-/OFF-delay operation III
   H: Signal OFF-delay operation III

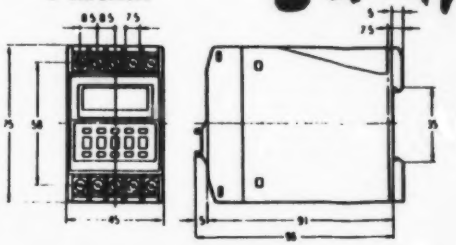
Loadout Samplers

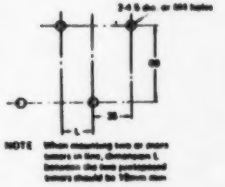
■ DIMENSIONS

• H3CA-A/H3CA-8(-8H)



• H3CA-FA



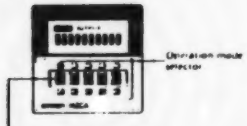


NOTE When mounting two or more units on line, dimension L between the two juxtaposed units should be 100mm min.

■ HINTS ON CORRECT USE

• HOW TO CHANGE OPERATION MODE

Operate the pushbuttons of the thumbwheel switch, located at the leftmost position on the front panel, to set the operation mode. Eight operation modes (A, B, C, D, E, F, G, and H) are selectable and the selected operation mode is displayed on the operation mode display window.



Operation mode selector

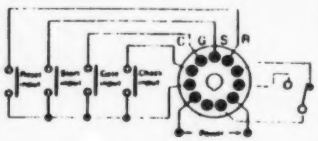
Operation mode display window
A: ON-delay operation
B: Flicker operation
C: Signal ON-/OFF-delay operation III
D: Signal OFF-delay operation III
E: Interval operation
F: One-shot flicker operation
G: Signal ON-/OFF-delay operation III
H: Signal OFF-delay operation III

NOTE The operation mode is fixed to A in type H3CA-8H.

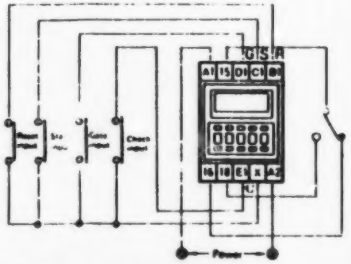
• HOW TO CHANGE TIME UNIT

■ CONNECTIONS

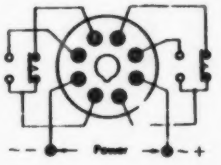
• H3CA-A



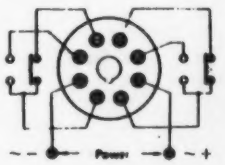
• H3CA-FA



• H3CA-8

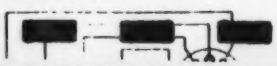


• H3CA-8H



• Connection of contact signal inputs
Connect the start input contact between terminals ① and ⑤, the reset input contact between terminals ③ and ⑤, the gate input contact between terminals ⑦ and ⑤, and the check input contact between terminals ⑨ and ⑤, respectively.

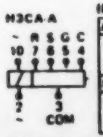
• Connection of solid-state signal inputs
Connect the start input transistor between terminals ② and ⑤, the reset input transistor between terminals ④ and ⑤, the gate input transistor between terminals ⑥ and ⑤, and the check input transistor between terminals ⑧ and ⑤, respectively.



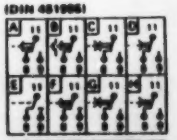
The input signal from the solid-state circuit is applied when output transistor Tr turns ON. In terms of signal voltage, the signal is input when it goes from high level to low level. Again, the residual voltage should be 1V max. when the transistor is ON. As the current output from the timer to Tr is approximately 0.1mA, this connection is possible provided the residual voltage is kept to the 1V maximum.

[redacted]

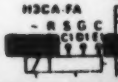
H3CA-A



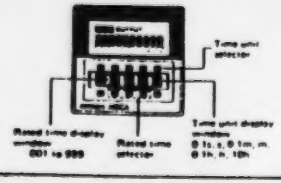
(DIN 41524)



H3CA-FA

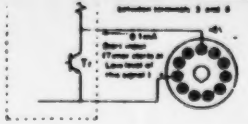


m, 0 1h, h, or 10h) are selectable and the selected time unit is displayed in the time unit display window.
The desired rated time is specified by operating the 3 thumbwheel switches in the middle of the front panel. The range of a rated time is 001 to 999 for each time unit.

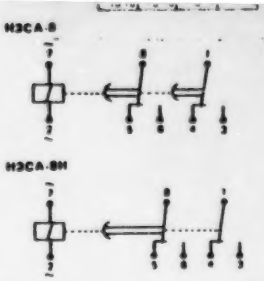

Time unit selector
Rated time display window 001 to 999
Rated time selector
Time unit display indications 0 1s, s, 0 1m, m, 0 1h, h, 10h

For each signal input contact, use a gold-plated contact of high contact reliability. Be sure that these input signals satisfy the following requirements: a resistance of 1kΩ max. and a residual voltage of 1V max. when the contact makes.

For signal input, use a transistor of open collector type with characteristics: V_{CEO} =20V min., V_{CEsat} =1V max., I_C=50mA min. and I_{CEO} =0.5μA max. In addition, be sure that these input signals satisfy the following requirements: a resistance of 1kΩ max. when the transistor is ON, residual voltage of 1V max. when the transistor is ON, and a resistance of 200kΩ min. when the transistor is OFF.
From a solid-state circuit (proximity switch, photoelectric switch, or the like) with the rated power supply voltage ranging from 6 to 30 VDC, input signals can also be applied by other than the open collector type transistor as shown in the following diagram.



NOTE:
Excepting the wirings for power supply circuit, avoid the laying of input signal wires in parallel or in the same conduit with high-tension or power lines. It is recommended to use shielded wires or wiring with independent metal conduits for the shortest possible distance.

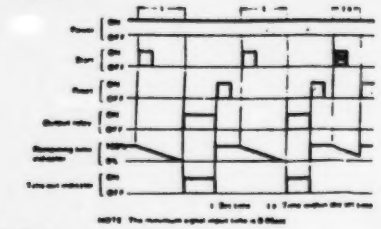


■ TIMING CHARTS (OPERATION MODES)

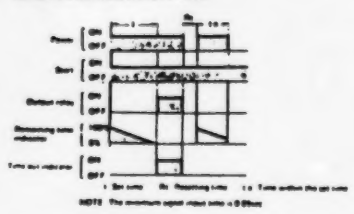
- H3CA-A(FA)

A mode ON-delay operation

- Signal start

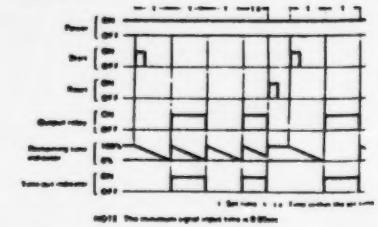


- Power-ON start/Power-OFF reset

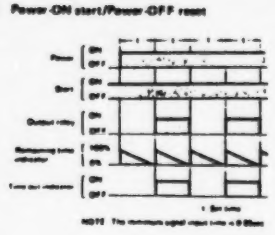


B mode Flicker operation

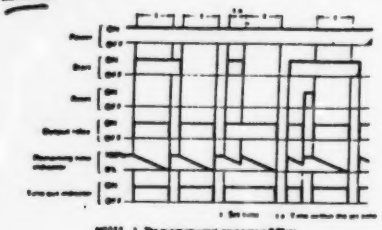
- Signal start



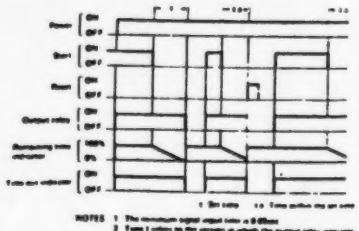
- Power-ON start/Power-OFF reset



C mode Signal ON-/OFF-delay operation (Type I)

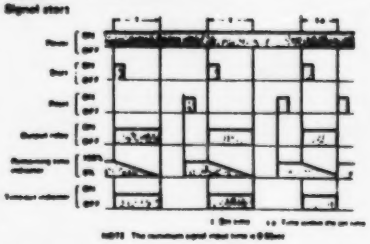


D mode Signal OFF-delay operation (Type I) (Set the mode selector to "D".)



E mode Interval operation

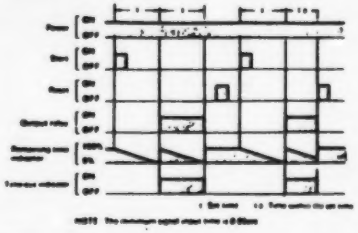
- Signal start



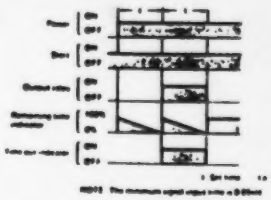
- Power-ON start/Power-OFF reset

F mode One-shot and flicker operation

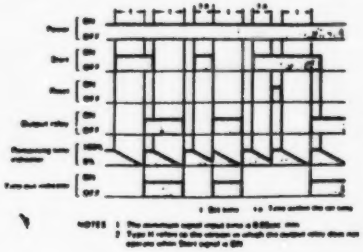
- Signal start



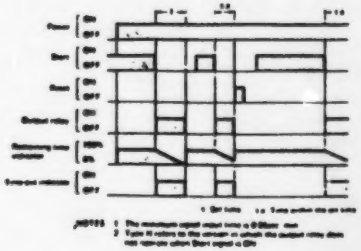
- Power-ON start/Power-OFF reset

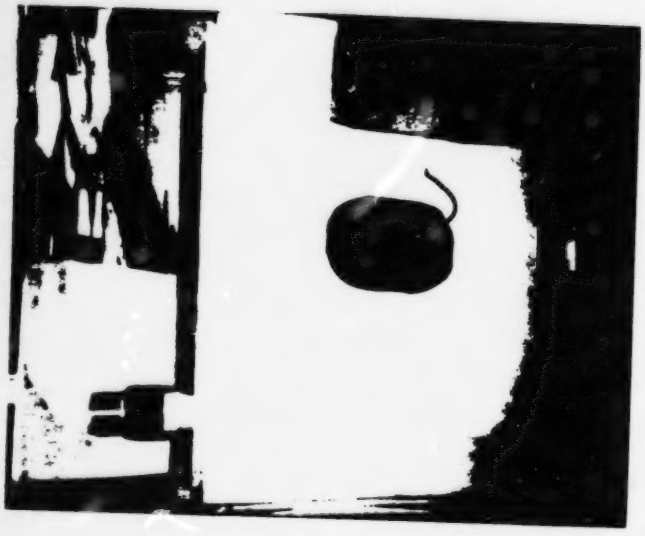


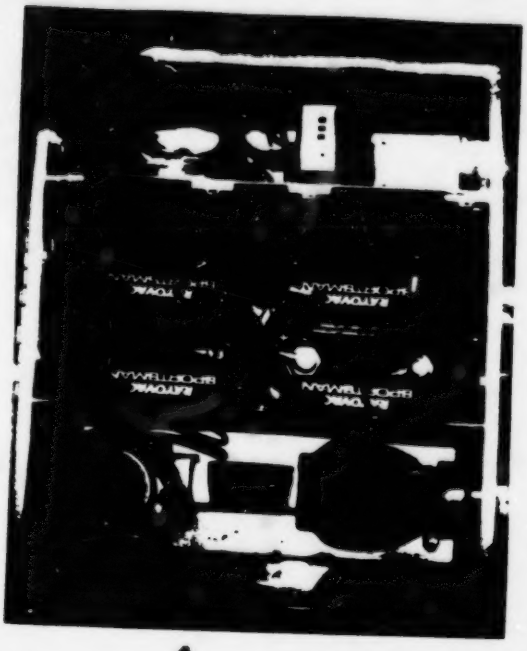
G mode Signal ON-/OFF-delay operation (Type II)



H mode Signal OFF-delay operation



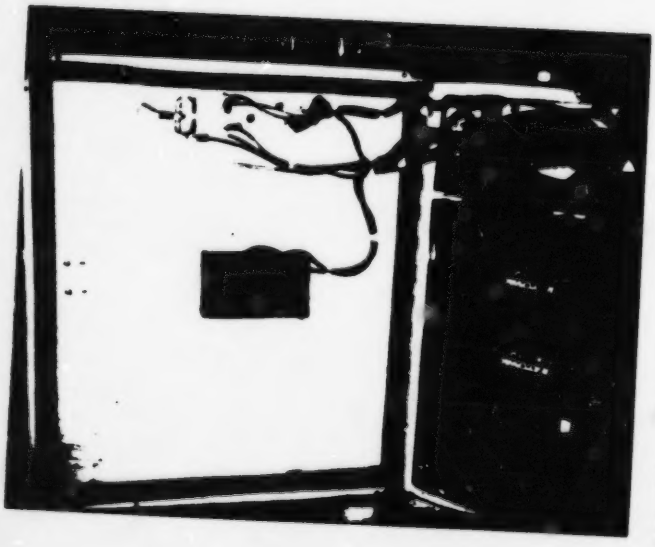




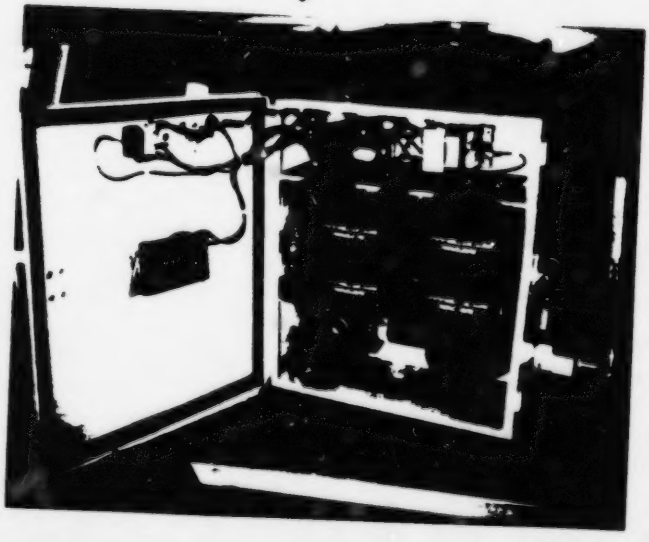
inside Box

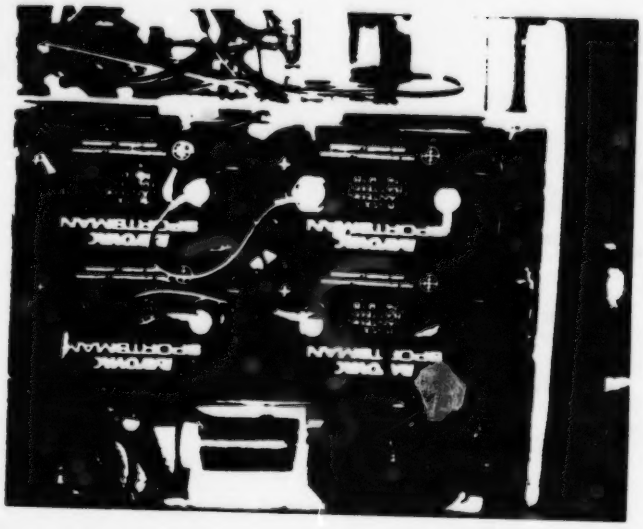
Front panel, water outlet

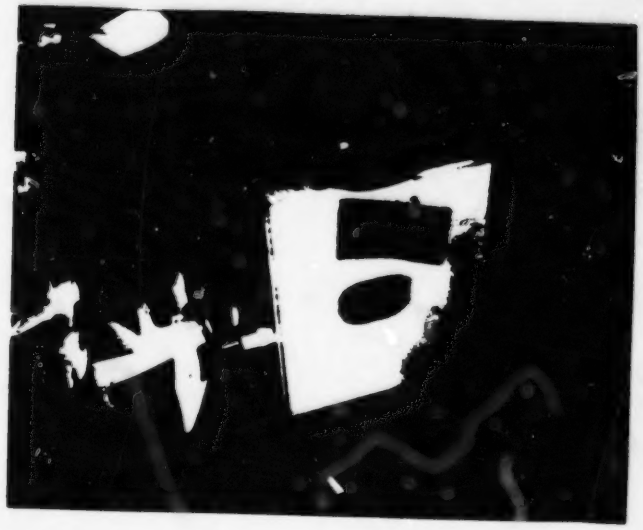
inside wire connections



inside Box.



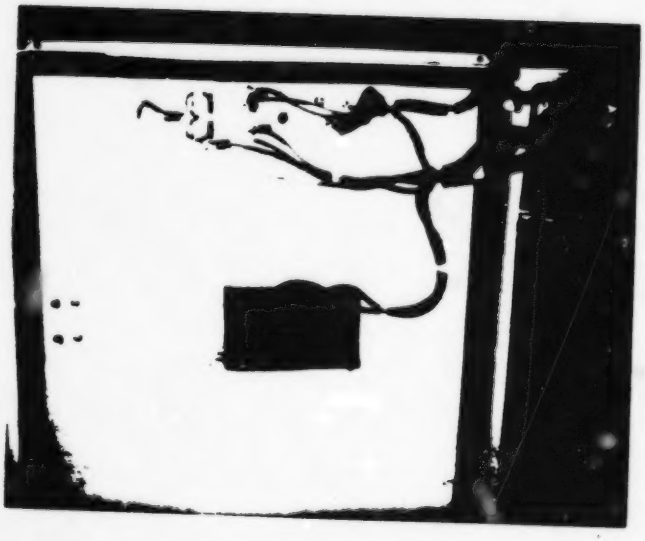




↑
Over all view, protective
Flap for lamps + switch

↖ Batteries (12 VDC)

↙ inside front panel

water in, lock

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